

METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 61 No. 364

FEBRUARY, 1960

Monthly: Two Shillings and Sixpence



Hale
Modern Malleable

That's

DEPENDABLE

& MACHINABLE

FOR EVERY INDUSTRY

HALE & HALE [TIPTON] LIMITED DUDLEY PORT Staffs

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PHONES TIPTON 1671/5

*MODERN MALLEABLE' (2nd Edition). If you have not had a copy, kindly send us a P.C. We shall be pleased to forward one, post free.



Impression by courtesy of Messrs. A. Hamilton & Sons Ltd.

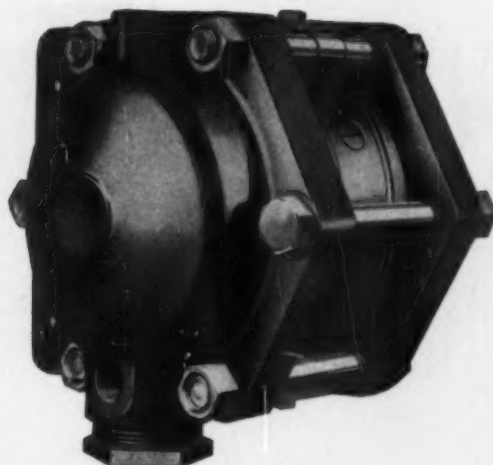
HEAT TREATMENT of castings

Furnaces and Equipment designed and built by

Fuel Furnaces Ltd

SHADY LANE • GREAT BARR • BIRMINGHAM 22A

New



Honeywell Bellows Meter

**unequalled for accuracy,
stability, versatility
in flow metering**

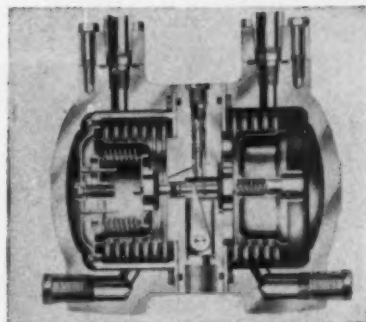
The new Honeywell Bellows Flow Meter gives the better performance demanded by its potential users. It's the most advanced meter body available today, with important advantages never before found in flow meters.

Some of its outstanding features:

Sensitive and accurate — Sensitive to within 0.05% of full scale . . . calibrated accuracy $\pm 0.5\%$ of full scale.

Leakproof — Between liquid fill and process fluid.

Automatically stabilised — Changes in meter body temperature or static pressure have no effect on output shaft position. The Honeywell Bellows



Meter operates efficiently in surrounding temperatures of between minus 40°F and plus 250°F.

Unmatched convenience features — Including fast range changing in the field . . . connections for both horizontal and vertical piping . . . quick calibration and adjustment . . . easy cleaning and servicing.

High corrosion resistance — Seamless, stainless steel formed bellows give long, trouble-free service with virtually all process fluids.

Fast, effective damping adjustment — New type pulsation check with rectangular orifice enables essentially linear damping adjustment . . . and you can adjust from outside the meter body during operation.

WRITE OR SEND THE COUPON TODAY TO:
Honeywell Controls Limited, Ruislip Road East,
Greenford, Middlesex. WAXlow 2333.

I am interested in your new Bellows Flow Meter
Please send me —
Specification sheet No. S292-2a.

NAME _____

POSITION _____

ADDRESS _____

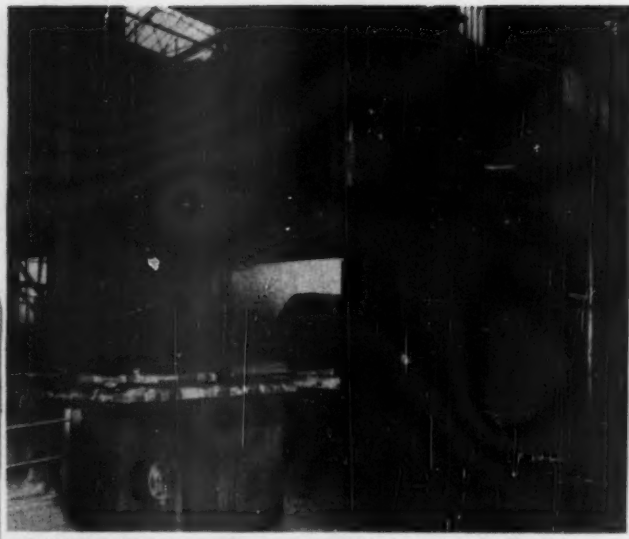
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Branch offices in London, Birmingham, Manchester, Sheffield, Leeds,
Middlesbrough, Cardiff, Glasgow, Dublin and throughout the world.

Honeywell



First in Control
SINCE 1885



CONTINUOUS BOGIE RE-HEATING FURNACES



We specialise in the design and construction of:—

- Open Hearth Furnaces
- Soaking Pits of all types
- Continuous Multi-zone Bloom and Slab Re-heating Furnaces
- Continuous Bogie type Ingot and Slab Heating Furnaces
- Furnaces for Aluminium Melting, Coil Annealing and Slab Re-heating
- Forge and Heat Treatment Furnaces
- Stress Relieving Furnaces
- Shipyards Plate and Bar Furnaces
- Modern Lime Burning Kilns



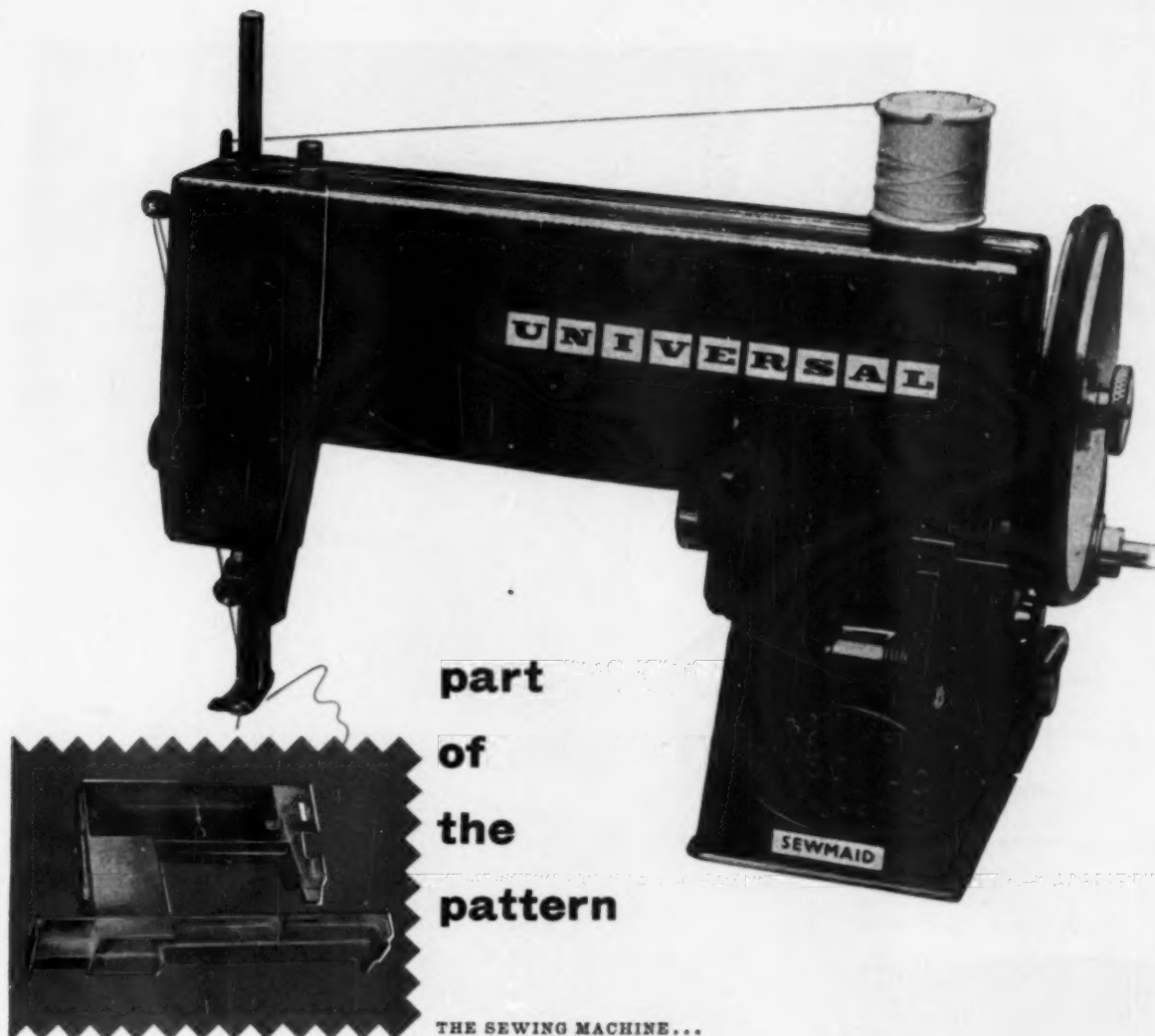
The illustrations are of the charging and discharging end of a Town's Gas Fired Furnace installed for The Chesterfield Tube Co., Ltd.

This unit is for heating billets prior to piercing and is also suitable for heat treating miscellaneous items in the soaking section.

PRIEST FURNACES LIMITED • LONGLANDS • MIDDLESBROUGH
also at TELEGRAPH BUILDINGS HIGH STREET SHEFFIELD



*The last word in
Furnace design*



part of the pattern

Body and base plate pressure die cast
complete as one unit in aluminium alloy
for Universal Sewing Machines Ltd

THE SEWING MACHINE...

a recurring feature of the British domestic scene.

And like countless other worthwhile products
it embodies castings made by Birmal.

Dependable Birmal! As necessary in their way
as stitches in a well made garment,
and as seldom in the public eye.

For more than 50 years Birmal skill has set the pattern
for so many first class castings...

in sewing machines and motor cars,
in nuclear engineering and aeroplanes.

And for many years to come,

Birmal will continue to be relied on
wherever the quality of castings counts.



Birmingham Aluminium Casting (1903) Co. Ltd

BIRMID WORKS SMETHWICK 40 STAFFS

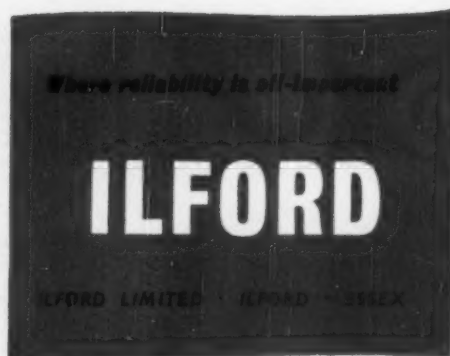


B·O·A·C takes good care of you
 —with **ILFORD Industrial B X-ray film**

High among the priorities of BOAC is safety. Behind the scenes at London Airport is some of the world's finest equipment, operated by highly trained personnel to ensure the reliability of every detail that contributes to safe operation.

Where even the smallest foreign particle may imperil life, nothing is left to chance. Complex units, such as engine oil coolers which cannot be dismantled for inspection, are therefore radiographically examined to detect accumulations of sludge, metal debris, and carbon particles which would spell danger if they circulated in the engine lubrication system.

For this examination, British Overseas Airways Corporation relies on ILFORD Industrial B X-ray film. Ilford has a reputation for reliability.

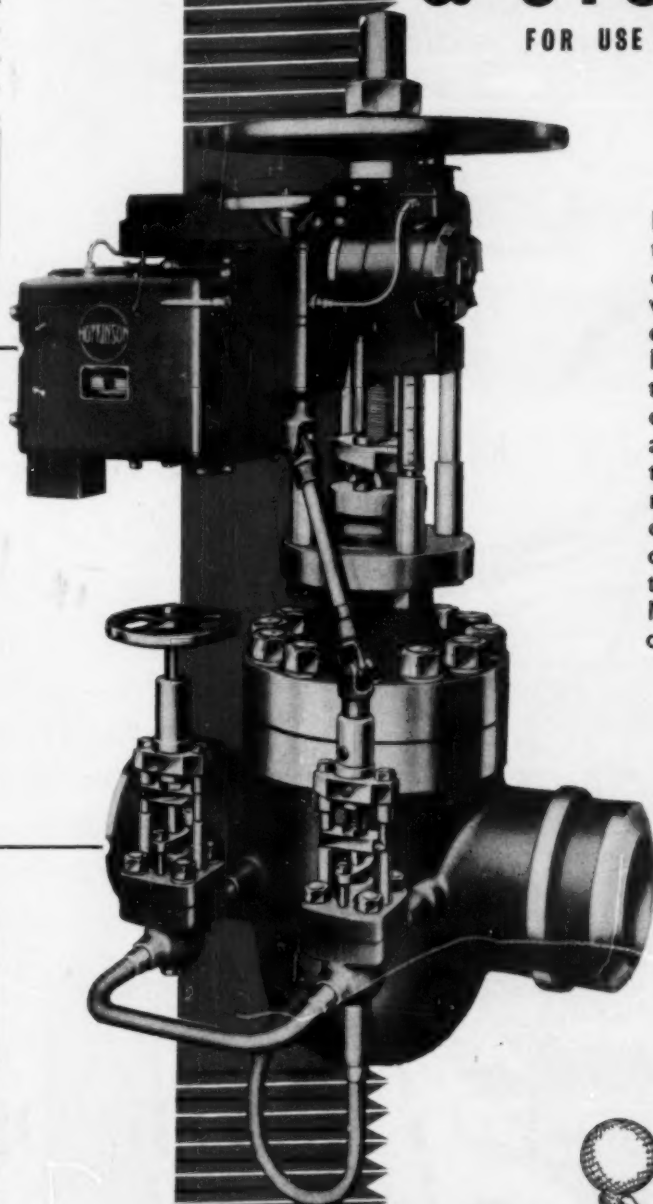


FIRTH BROWN

BOLT & STUD STEELS

FOR USE AT ELEVATED TEMPERATURES

CRM2 - 1% CHROMIUM MOLYBDENUM STEEL



Firth Brown CRM2 steel is typical of the three steels offered for Bolts and Studs which have to operate at elevated temperatures for long periods. CRM2 is designed to meet a certain level of creep-resistance together with ability to develop a high tensile strength and a good resistance to embrittlement during service. Full particulars of the Firth Brown steels in this range are in Publication No. 226 which is available at once upon request.

Electrically operated Parallel Slide Valve, showing bypasses and equalizing pipe connections for elevated pressure and temperature service, with stud bolts made in CRM2 steel.

Photograph by courtesy of Messrs. Hopkinsons Ltd., Huddersfield.

FIRTH BROWN

ERS • FORGEMASTERS • STEEL FOUNDERS • HEAVY ENGINEERS

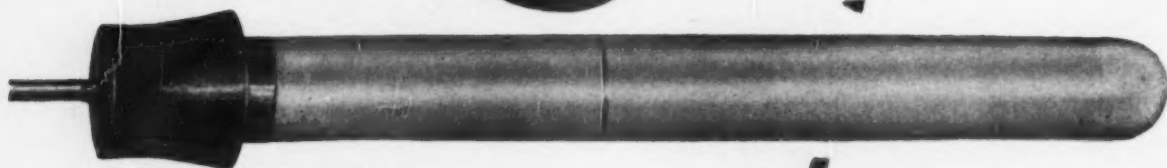
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...devilish

good

acid heating



Do you accept waste with a devil-may-care shrug . . . or do something about it with Vitreosil Electric immersion heating? Controlled immersion heating in the electro-plating or pickling bath costs less, saves time, and improves output. *Like more information?* Write and we'll be devilish quick in replying!

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1500°C

Heating Rods for High Temperatures

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A wide range of Silit Rods of equal diameter throughout can also be supplied, diameters ranging from $\frac{1}{8}$ " - 1 1/2".

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Siemens 597

Important
NEW information
for users of
gunmetal castings

Improved Gunmetals for quality castings

THE MOND NICKEL COMPANY LIMITED



Here's news about Improved Gunmetals

So far no standard Gunmetal available has been capable of providing the ideal combination of properties for quality castings. Now, the Mond Nickel Company Limited introduce two entirely *new* and *improved* Gunmetals containing Nickel which meet this ideal with economy.

The booklet opposite shows in detail why these improved materials are better than standard materials, illustrates their many applications and shows how *you* can benefit from using improved Gunmetals.

IMPROVED GUNMETALS PROVIDE:

*Uniformly high mechanical properties and pressure
tightness in castings of variable section.
Good castability · Ease of production*

Send for this booklet now



Please send me a copy of your booklet on 'Improved Gunmetals for Quality Castings'.

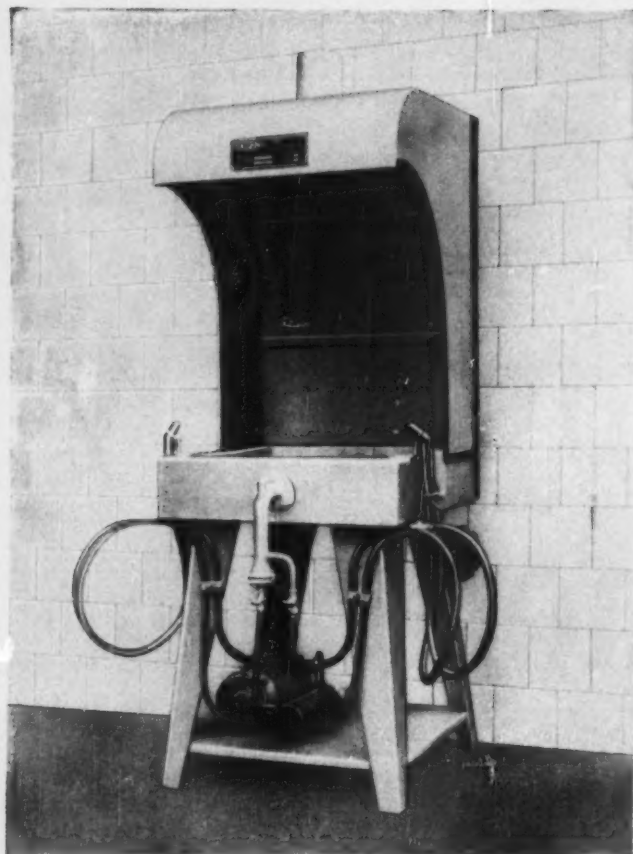
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ADDRESS _____

The Mond Nickel Company Limited, Thames House, Millbank, London, S.W.1



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GAS BLAST COMBINED FORGE AND BRAZING HEARTH

Complete with Motor Driven Positive Air Blower, two Gas Blast Blow Pipes and one Gas Blast Burner. Suitable for Tube bending up to 1 in. diameter.

Size of Hearth, 20 in. × 20 in. × 4 in.

Gas Consumption, 200 cu. ft. per hour maximum.



NATURAL DRAUGHT GAS FIRED SALT BATH SUITABLE FOR CYANIDE OR NEUTRAL SALTS

Suitable for temperatures up to 900° C.

Obtainable in the following sizes :

8 in. dia. × 8 in. deep, gas consumption 300 cu. ft./hr.

8 in. dia. × 10 in. deep, gas consumption 350 cu. ft./hr.

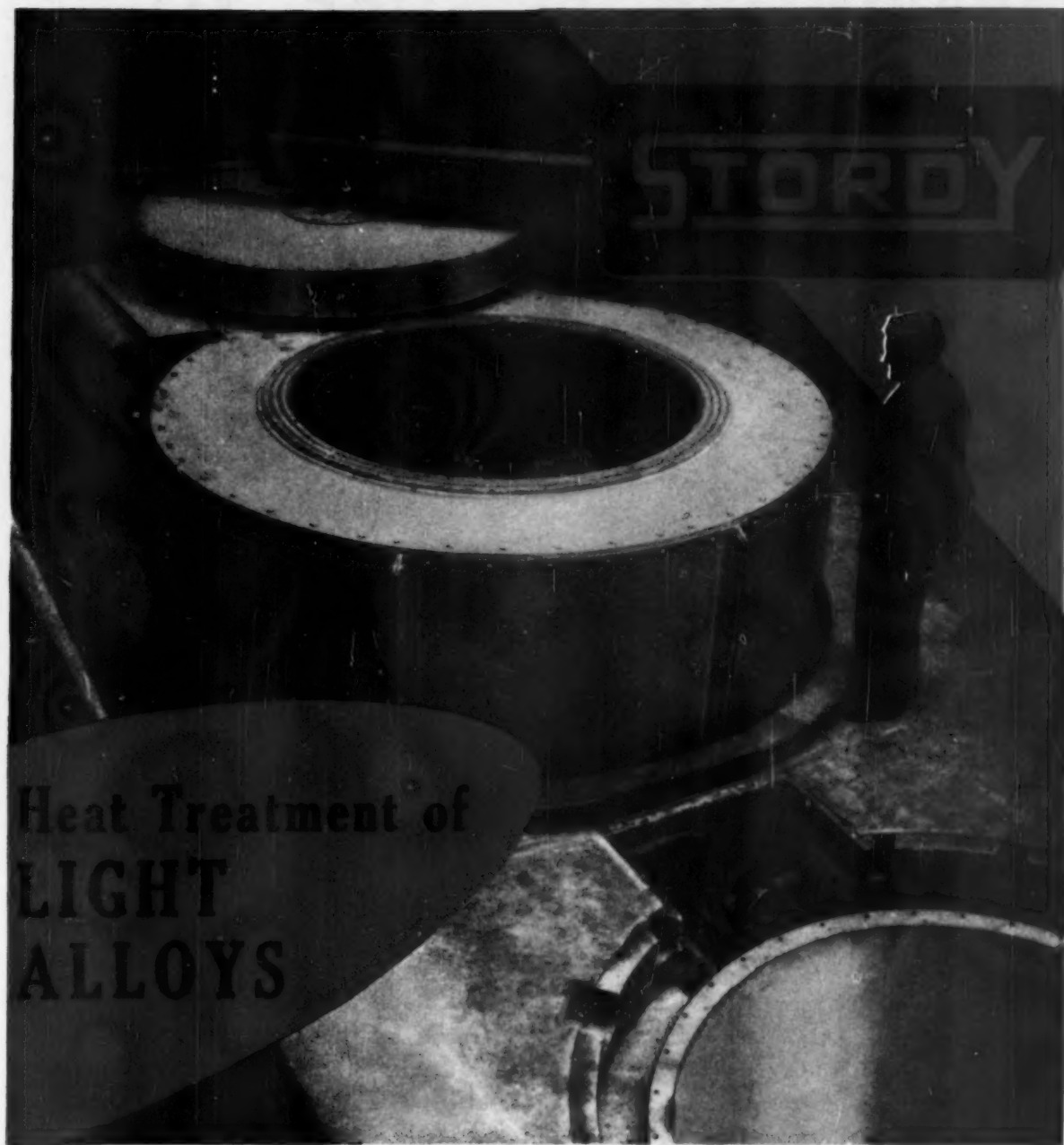
10 in. dia. × 12 in. deep, gas consumption 400 cu. ft./hr.

Time to heat up—1½ hours.

Manufactured by



7, HOLYROOD STREET · BERMONDSEY · LONDON, S.E.1



Heat Treatment of LIGHT ALLOYS

Greater efficiency, more precise control, higher output with considerably less maintenance and running costs—these are the features that place these

STORDY Electric Furnaces ahead for light alloy treatment. Unit construction of heater battery allows ready derating adjustment for precipitation treatment and annealing—with same precise temperature control. In addition, the heater battery is remote from the furnace chamber and therefore easily accessible for inspection without dismantling. The large capacity centrifugal fan gives greater air circulation.

The furnace illustrated is for the heat treatment of extruded sections—work dimensions 5 ft. diameter by 8 ft. deep.

STORDY ENGINEERING LIMITED
CUMBRIA HOUSE • GOLDTHORN HILL • WOLVERHAMPTON

SM/SY: 2807

INSULATION of CORE STOVES ENAMELLING OVENS etc.

**This
DATA
may lower
your costs**



The use of Therbloc Mineral Wool Slabs (14/16 lbs. per cu.ft. density) as a backing insulant at interface temperatures of up to 815°F is well established in the furnace industry. However, where lower temperatures are involved, for example core stoves and paint

booths S.R.10 (9/10 lbs. per cu.ft. density) is an extremely valuable material not only for maintaining temperatures and reducing fuel bills but also to make working conditions more acceptable to operators.



(Regd. Trade Mark)

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Incorporating Jones & Broadbent Ltd.

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To Stillite Products Ltd., 15 Whitehall, London, S.W.1.

NAME.....

ADDRESS

Just attach this coupon to your letterhead

METALLURGIA

COMPLETE HEAT TREATMENT PLANT

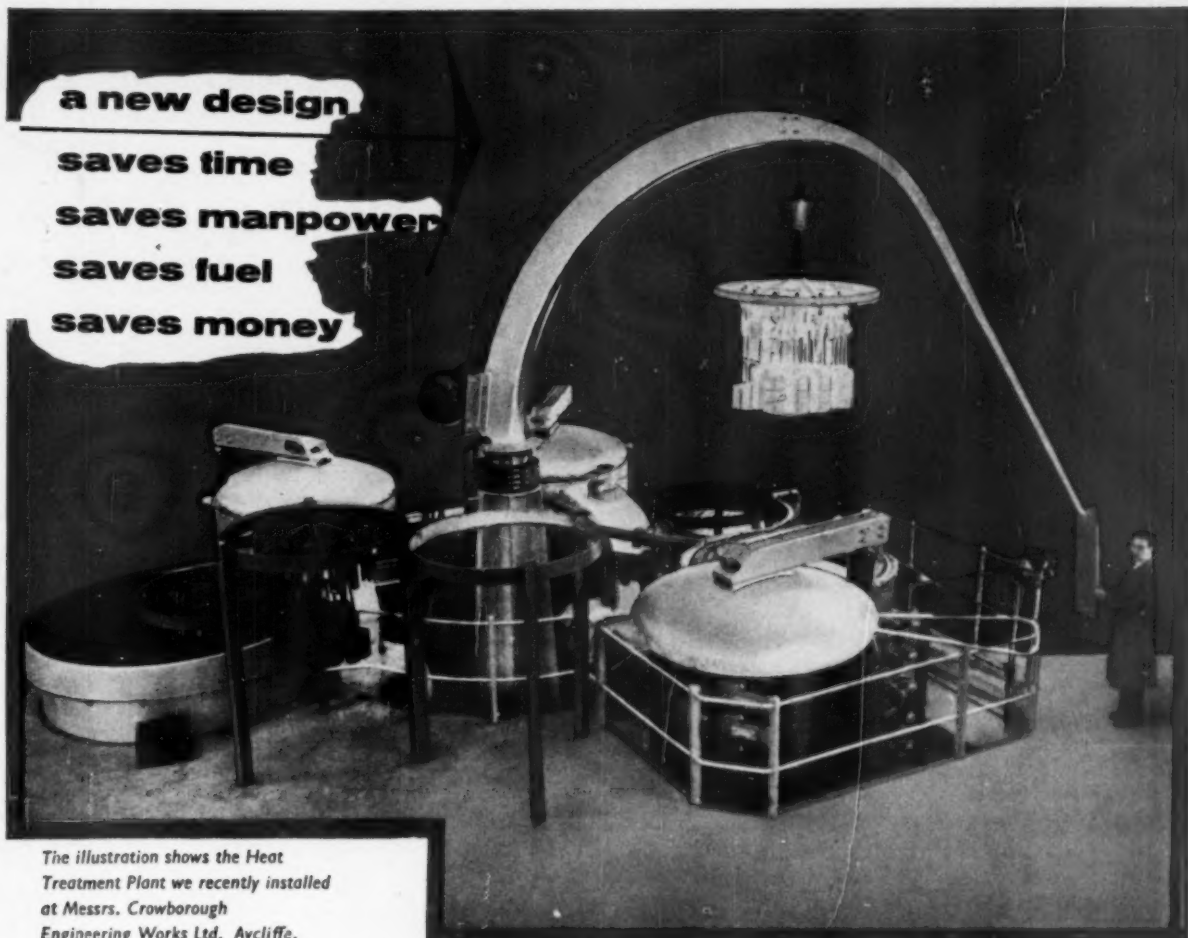
a new design

saves time

saves manpower

saves fuel

saves money



The illustration shows the Heat Treatment Plant we recently installed at Messrs. Crowborough Engineering Works Ltd. Aycliffe.

The complete unit installation at Aycliffe consists of Hardening Furnace, two Tempering Furnaces, Water Quench Tank, Oil Quench Tank, Loading and Unloading Racks. The unit is serviced by a fully-automatic, centrally-located, electrically-operated crane. The two re-circulating Tempering Furnaces utilise the waste heat from the Hardening Furnace. Supplementary gas is automatically provided when necessary.

Further details are available on enquiry to :—

STERLING FURNACES LIMITED

13, Marton Road, MIDDLESBROUGH

Telephone : 43328. Telegrams : Sterling, Middlesbrough

Scientific Means

The AEI range of Scientific Equipment includes apparatus for the investigation of metallurgical, chemical and biological problems in research, production and processing. These equipments cover a wide selection of specialised scientific apparatus.

to Scientific Ends



Associated Electrical Industries Limited
INSTRUMENTATION DIVISION
Scientific Apparatus & X-Ray Dept.
Trafford Park, Manchester, 17



THE X-RAY MICRO-ANALYSER

permits the quantitative chemical analysis of volumes of material down to 1 micron cube. It is designed to cover the range of elements from uranium to titanium. With additional equipment—a proportional counter, amplifier and pulse height analyser—the range can be extended from titanium to aluminium.

In this micrograph each black dot represents an area of approximately 1 micron diameter studied by the x-ray micro-analyser at the surface of a bismuth copper aluminium alloy. Five separate phases occurring in the fusion of the alloy were identified.

Let us look into your problem

Experts of our Advisory Service can almost certainly help you with problems of scientific investigation in any of the fields mentioned below.

ELECTRON MICROSCOPY
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CRYSTALLOGRAPHY
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MATERIALS IRRADIATION
HIGH VACUUM ENGINEERING
X-RAY MICRO-ANALYSIS

14. 10. 1977

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CEMENTS, PLASTICS AND CASTABLES

From our extensive range of Refractory Cements, Plastics and Castables, covering a wide range of properties, we can supply the correct material for most industrial applications.



REFRACTORY CEMENTS

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"Makseccar 11" Refractory Cement

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Air-setting



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Please ask for a copy of our No. 4 Pamphlet.

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Cronite

A GOOD NAME FOR NICKEL CHROME ALLOYS

HEAT RESISTING CASTINGS OF ALL TYPES

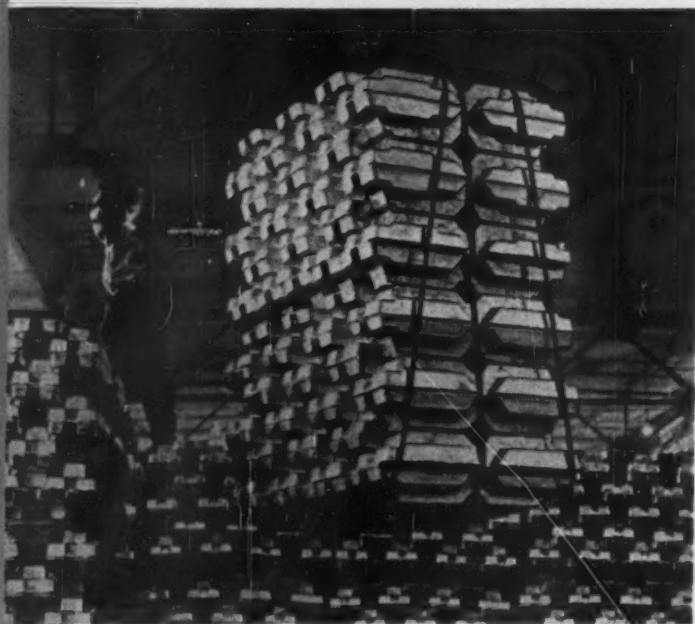
THE CRONITE FOUNDRY CO., LTD.

LAWRENCE ROAD, TOTTENHAM, LONDON, N.15. TELEPHONE: STA.4237

ALCAN

TRI-LOK

a new form of ingot

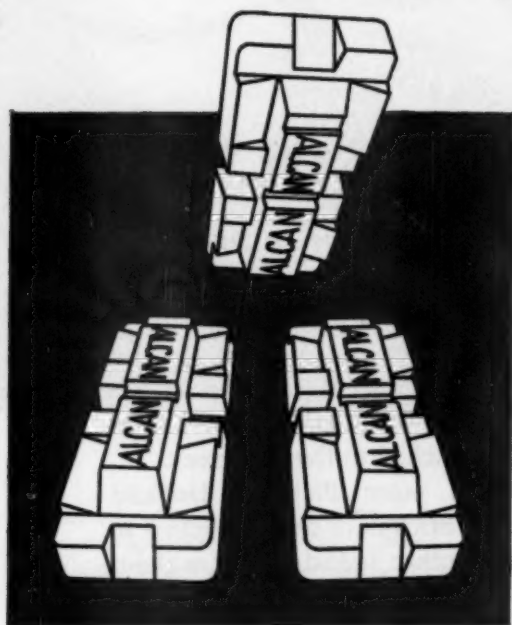


ALCAN (U.K.) LIMITED (specialists in aluminium ingot) have introduced a new and brilliant development in ingot design, the TRI-LOK.

This ingenious interlocking shape enables ALCAN ingots to be stacked more compactly with greater safety and more speed because they 'mate' one to another—and resist lateral and lengthwise displacement. The consequent ease of handling has already given measurable cost savings in loading and storage operations to many ALCAN customers.

cuts handling costs!

for easier, speedier, safer handling



TSW/126

ALCAN 'TRI-LOK' ingots readily separate by lifting, though when stacked they interlock three ways and provide a bundle ready for fast handling by fork lift truck.

For further details write to:—

ALCAN (U.K.) LIMITED
(formerly Aluminium Union Ltd.)

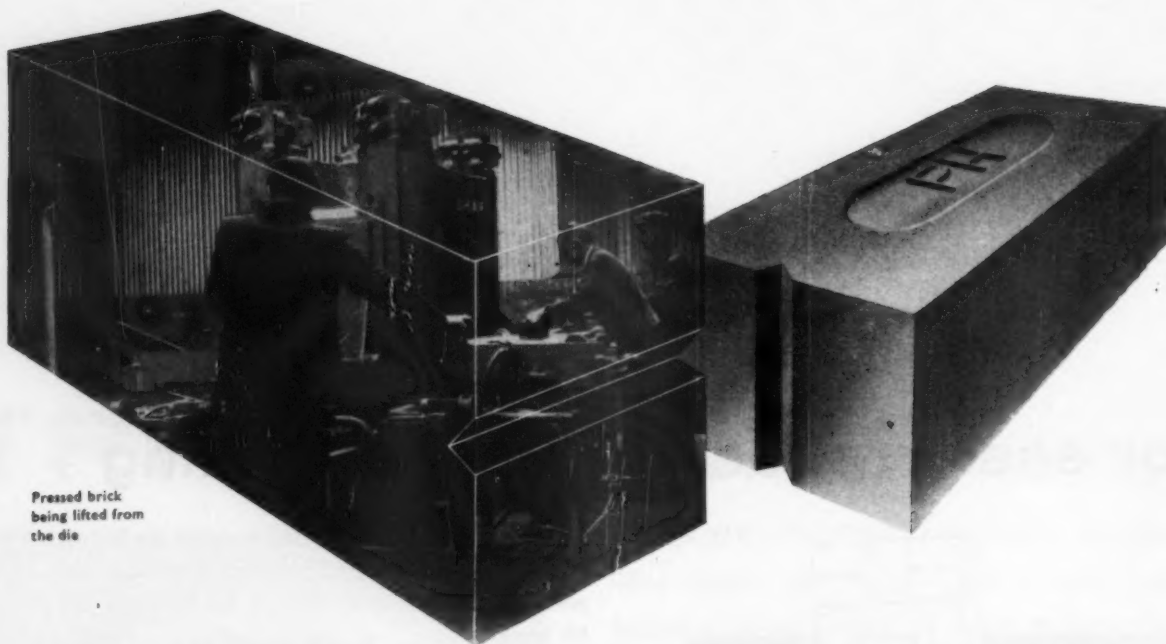
LONDON: Aluminium Canada House · 30 Berkeley Square · W1
Telephone: Mayfair 9721 · Cable: Alcanuk · London

BIRMINGHAM: Gazette Buildings · Corporation Street
Telephone: Central 1446

MANCHESTER: National House · 36 St. Ann Street
Telephone: Blackfriars 9772



ALUMINIUM LIMITED OF CANADA



Pressed brick
being lifted from
the die

PRESSING PROBLEM SOLVED

*Pickford Holland install the latest hydraulic presses
for standard and special shapes*

Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control

of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.



PICKFORD HOLLAND *Refractory Bricks*

Consistent in Size, Shape, Texture and Performance

PICKFORD, HOLLAND & CO. LTD., 381 FULWOOD ROAD, SHEFFIELD 10. TELEPHONE 33921

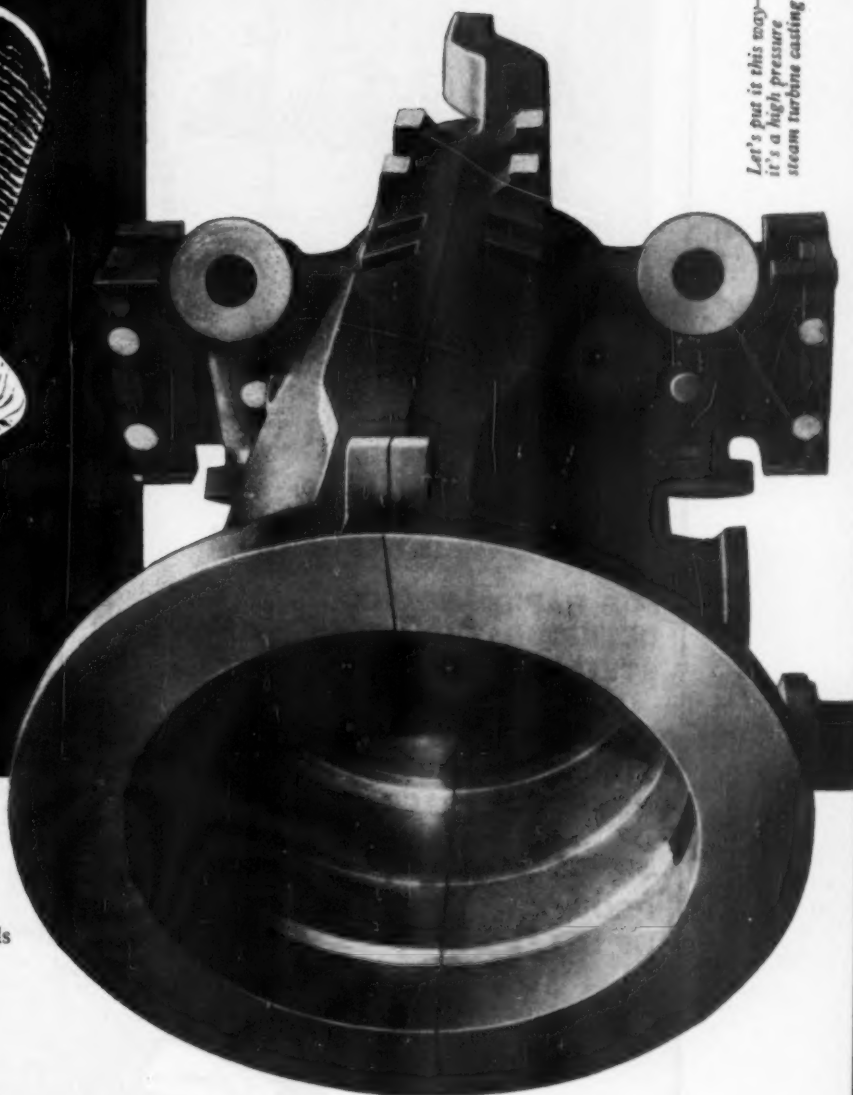
Black Magic



There is no witchcraft, really, about the unvarying high quality of David Brown castings — though there are many other kinds of craft involved in their production. At the Penistone Foundries, the crafts of the steel maker, pattern maker and moulder are brought together and, with other skills, are co-ordinated into a complex production unit of supreme efficiency. Backed by unique metallurgical resources and using the most up-to-date plant and techniques, this organisation offers a completely reliable service for all types of steel casting.

Next time you have a casting problem, whatever the application, call in David Brown—first!

Brown Magic



Let's put it this way—
it's a high pressure
steam turbine casting

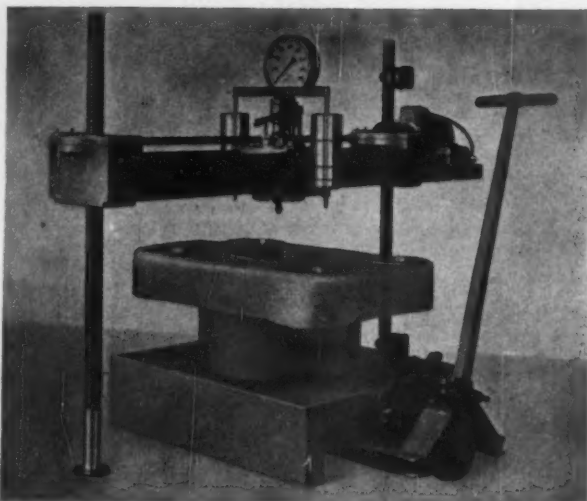
DAVID BROWN

THE DAVID BROWN CORPORATION (SALES) LIMITED

FOUNDRIES DIVISION, PENISTONE, NR. SHEFFIELD.

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JACKMAN FOR HARDNESS TESTING EQUIPMENT



BRINELL TEST MACHINES

WE SHOW A BEAM TYPE
BRINELL MOTORISED FOR
VERTICAL MOVEMENT.

TEST HEAD CAN BE SLID
ALONG BEAM BY HAND.

WIDTH BETWEEN COLUMNS 52"
HEIGHT UNDER TEST BALL
6" TO 60"

STANDARD BENCH TYPE AND
OTHER SPECIAL MACHINES
AVAILABLE.

PLEASE WRITE FOR BULLETIN No. 2

ALPHA CARBOMETER

FOR RAPID AND ACCURATE
DETERMINATION OF CARBON IN
STEEL BATHS.

TOTAL TIME OF MAKING TEST $1\frac{1}{2}$ - $2\frac{1}{2}$
MINUTES INCLUDING PREPARATION
OF SPECIMEN. ACCURACY IS $\pm 0.01\%$

SIMPLE TO OPERATE.
PROVIDES COMPLETE CONTROL
OF STEEL BATH.



USED IN THE
LEADING STEEL
WORKS OF THE
WORLD.

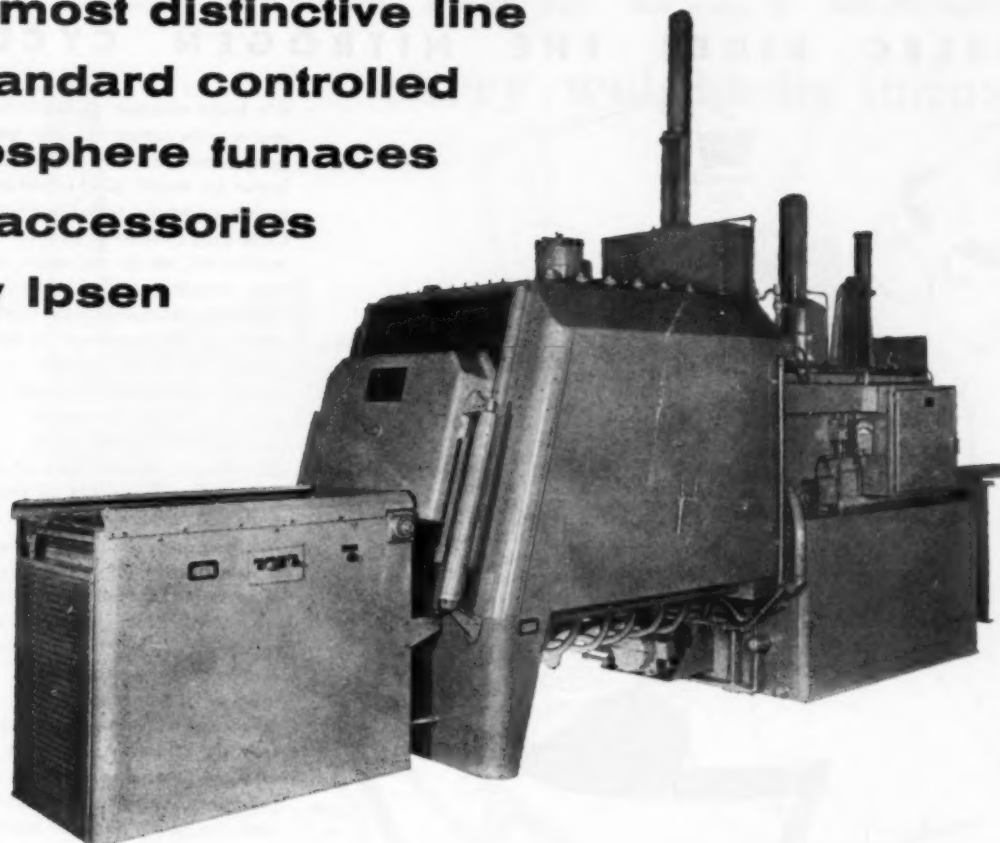
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Telephone: DEAnsgate 4648 (3 lines)

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**The most distinctive line
of standard controlled
atmosphere furnaces
and accessories
...by Ipsen**



Standard Ipsen controlled atmosphere furnaces are available in more than 85 different sizes and types. Capacities range from 25-pounds-per-hour laboratory models to 4000-pounds-per-hour production heat treating units.

All Ipsen furnaces have 100% forced convection heating for carburizing, light case carbonitriding, neutral hardening, and marquenching. The Ipsen line includes:

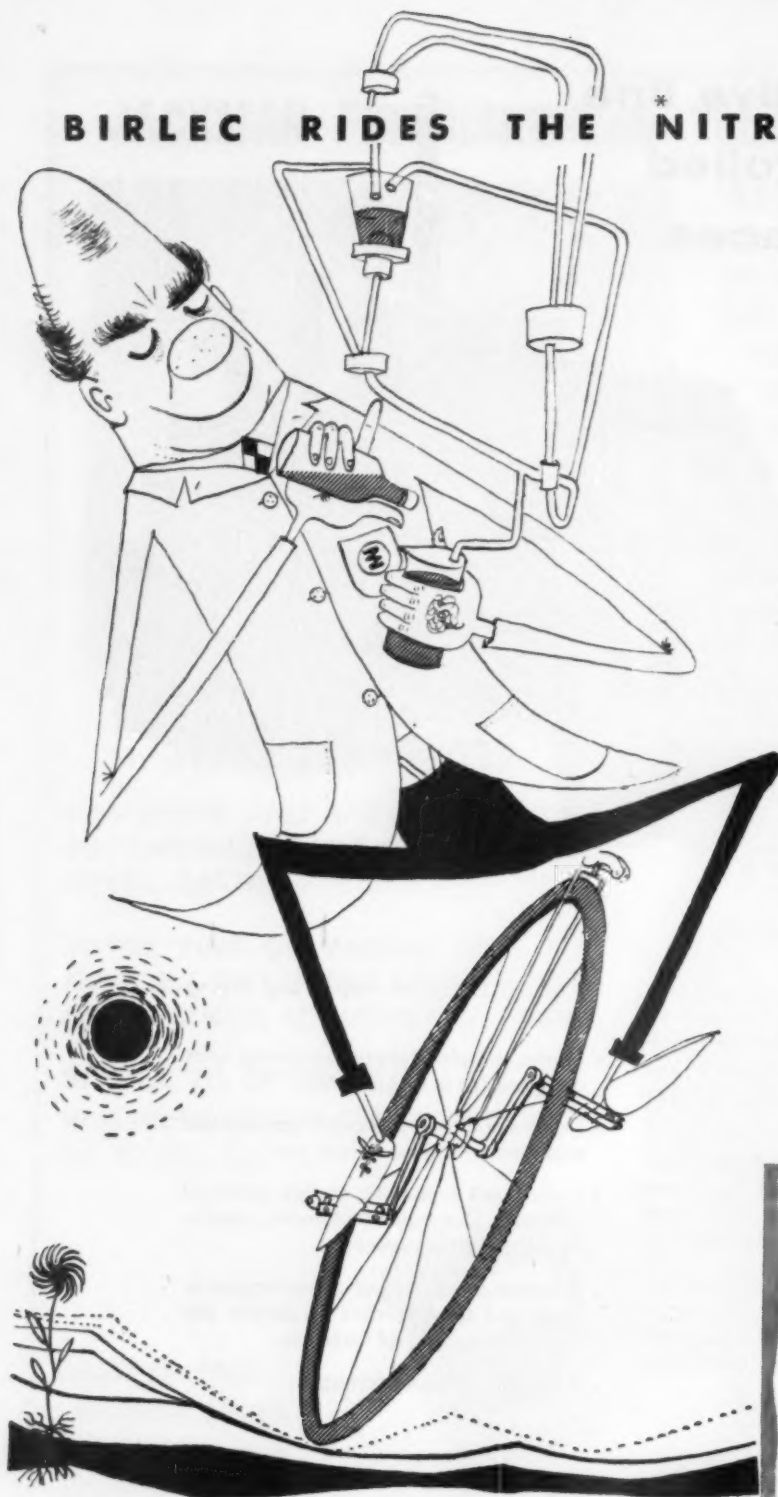
- "Straight-through" controlled atmosphere heat treating units with single zone, double zone, or multi-zone heating chambers. Single and double row "pusher" furnaces.
- Washing units with rinsing and drying optional.
- Controlled atmosphere tempering units designed for bright drawing.
- Endothermic or exothermic generators, and ammonia dissociators.
- Carbotronik automatic carbon potential controls; Dewtronik automatic atmosphere dewpoint controls.
- Automatic loading and unloading equipment and transfer cars to service one unit, or a battery of furnaces.
- Automatic vacuum furnaces.

We'll gladly call and supply complete information at your convenience.



IPSEN INDUSTRIES, INC., 53 VICTORIA ROAD, SURBITON, SURREY, Phone: ELMbridge 2021

BIRLEC RIDES THE * NITROGEN CYCLE



We build nitrogen generators—and a wide range of other gas generators, too. The fact had better be stated quickly before the purists point out that the nitrogen cycle also concerns organic matter: no, we do not make nitrogen from decomposing animal tissue. Specially designed generators separate nitrogen from air by the combustion of fuel, which converts the oxygen content into carbon dioxide and water. We deal with these waste constituents, too, but one of our engineers will explain all that. Protective atmospheres for furnaces, including annealing of transformer laminations; purging of electric lamps and handling of semi-conductors; prevention of oxidation in chemical processes and in packing sensitive foodstuffs; handling of inflammable liquids in petroleum refining; all these processes employ nitrogen protection. Estimates of capital and running costs for Birlec nitrogen generators are available on request.

*... if there were other gas cycles we'd ride those also, as we build generators for hydrogen, carbon dioxide, inert gases, and furnace atmospheres, in addition to nitrogen.

Dryer and Gas Plant Division of
AEI-Birlec Limited

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LONDON
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SM/B4995

SHELL-MEX AND B.P. GASES

carry weight in industry



Birlec Generators producing special atmospheres for gas carburizing at E.N.V. Engineering Company Limited.



Propane and Butane are now available to industry from the great British refineries of the Shell, Eagle and BP Groups. They are petroleum gases delivered and stored as liquids under moderate pressure.

Propane supplied by Shell-Mex and B.P. Gases Limited provides industry not only with a high calorific value fuel gas (approximately 2,500 B.t.u./cubic foot) but also with an excellent medium for the production of special furnace atmospheres.

It is widely used for gas carburizing, carbonitriding and bright annealing of ferrous and non-ferrous metals.

'Bottogas' Butane is used as a fuel for fork lift trucks and for many other specialised applications.



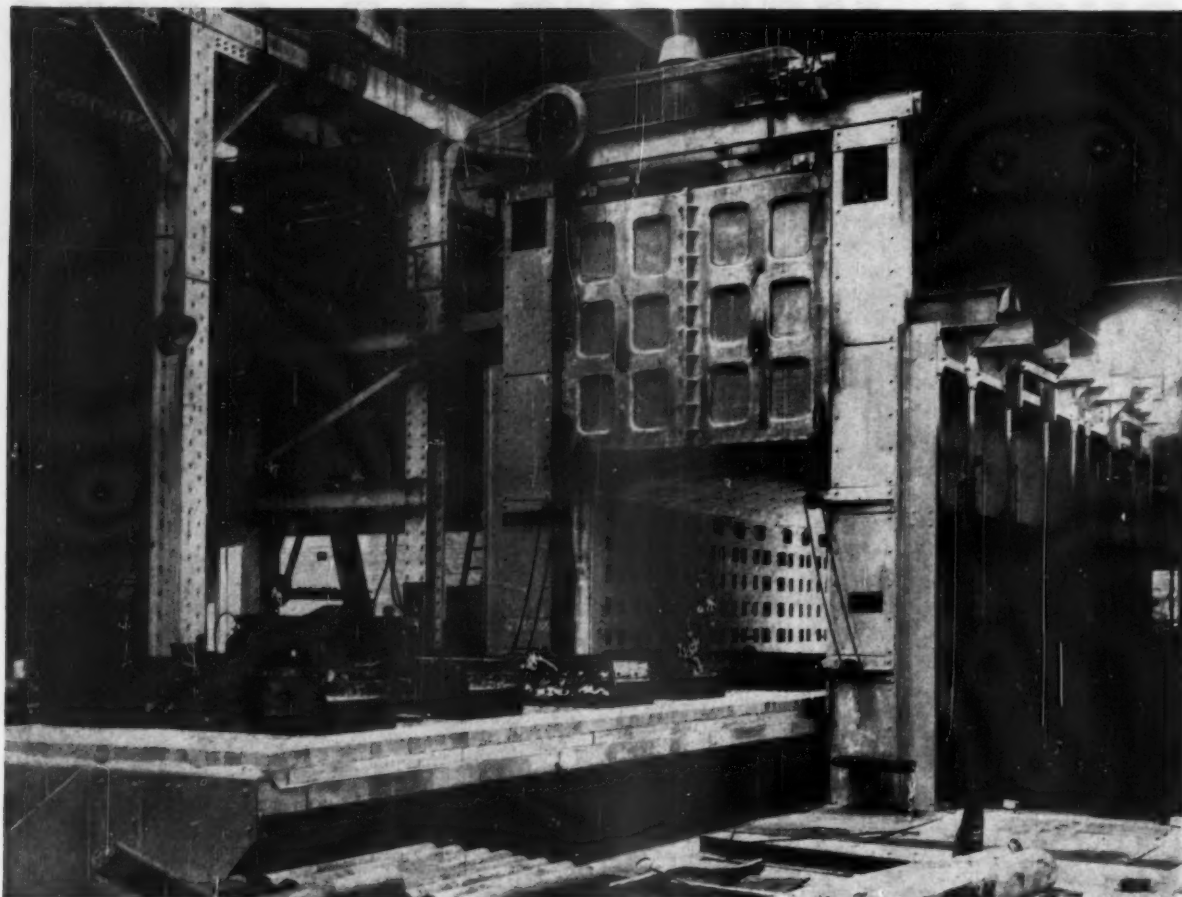
SHELL-MEX AND B.P. GASES LIMITED

(Regd. users of trade marks)

"The biggest distributors of Propane in the U.K."

CECIL CHAMBERS 76-86 STRAND LONDON WC2 Telephone: TEMple Bar 1234





Photograph by courtesy of Messrs. Thos. Firth & John Brown Ltd., Sheffield.

Brayshaw

Town's Gas Fired Bogie Hearth Tempering Furnace

*of the products recirculation type
installed at Messrs. Thos. Firth & John Brown Ltd., Sheffield.*

the above illustration is one of the many
installations supplied to leading manufacturers
Brayshaw Industrial Furnaces for all
purposes including: -----

*Ask . . . BRAYSHAW the specialists in
design and construction of
internationally famous Furnaces*

BRAYSHAW FURNACES LTD.,

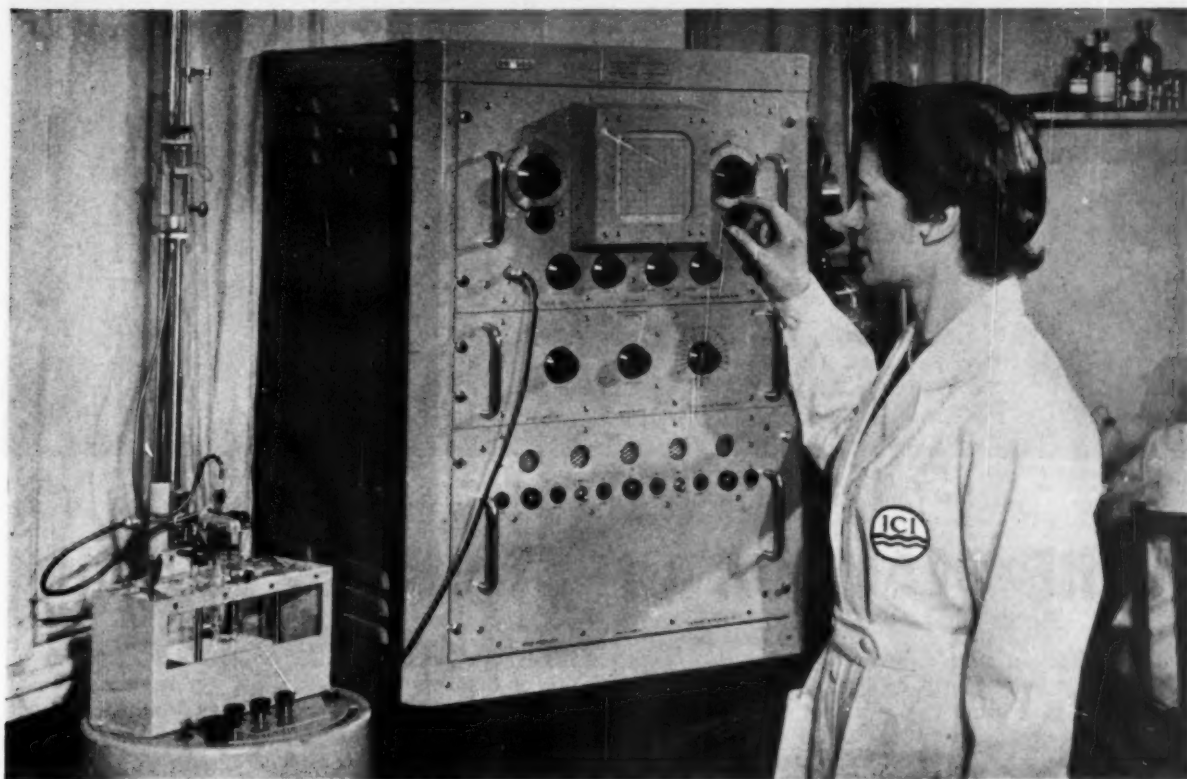
BELLE VUE WORKS, MANCHESTER 12

**Telephone East 1046 (3 lines) Telegrams Hardening Manchester
London Office 21 Liverpool Street, E.C.2 Telephone Avenue 1617/6**

**ANNEALING
HARDENING
TEMPERING
CARBURISING
FORGING
GALVANISING
MELTING**

by Gas - Oil - Electricity

This is polarography — the easy way!



Photograph by courtesy of I.C.I. Ltd. (paints division)

Analysts all over the world have found how easy it is to get rapid and accurate analyses with our Cathode Ray Polarograph. It is quick in action, gives direct or derivative readings, and has that extra sensitivity you so often require. Its easily readable peak polarograms repeat every seven seconds. Your laboratory is wasting expensive time without this indispensable instrument.

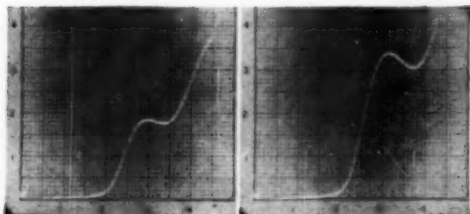
SPECIFICATION

DISPLAY. six-inch diameter cathode ray tube, with a 9cm. square graticule printed on its flat, long persistence screen.

VOLTAGE SWEEP. Rate: 0.3 volt per second (fixed). Range: 0.5 volt per sweep approximately (fixed). Start Potential: + 0.5 volt to -2.0 volts (variable). Sweep Time: One polarogram per mercury drop with seven second repetition.

PLATE ONE

PLATE TWO



TYPICAL APPLICATION FOR CATHODE RAY POLAROGRAPH

Determination of Cyanide in Effluent Sample. Introduce 5 ml. sample into two 10 ml. volumetric flasks, into one flask add 0.2 ml. of a standard cyanide solution, (50 µg/ml. CN'), and make each up to the mark with 0.2N NaOH. Shake well. Transfer 5 ml. from each flask into polarographic cells, and de-aerate with nitrogen for 3 mins. Record the polarograms applying anodic oxidation on start potential -0.4V and scale factor 1.0.

$$\begin{aligned} x \mu\text{g CN}' + 5 \mu\text{g CN}' &= 34 \text{ divisions (Plate 2)} \\ x \mu\text{g CN}' &= 18.5 \text{ divisions (Plate 1)} \\ \therefore 5 \mu\text{g CN}' &= 15.5 \text{ divisions} \\ x &= \frac{5 \times 18.5}{15.5} \mu\text{g} \\ x &= 6.0 \mu\text{g} \\ \text{Volume of sample in cell} &= 2.5 \text{ ml.} \\ \therefore \text{Concentration of CN}' \text{ in sample} &= 2.4 \mu\text{g/ml.} \end{aligned}$$

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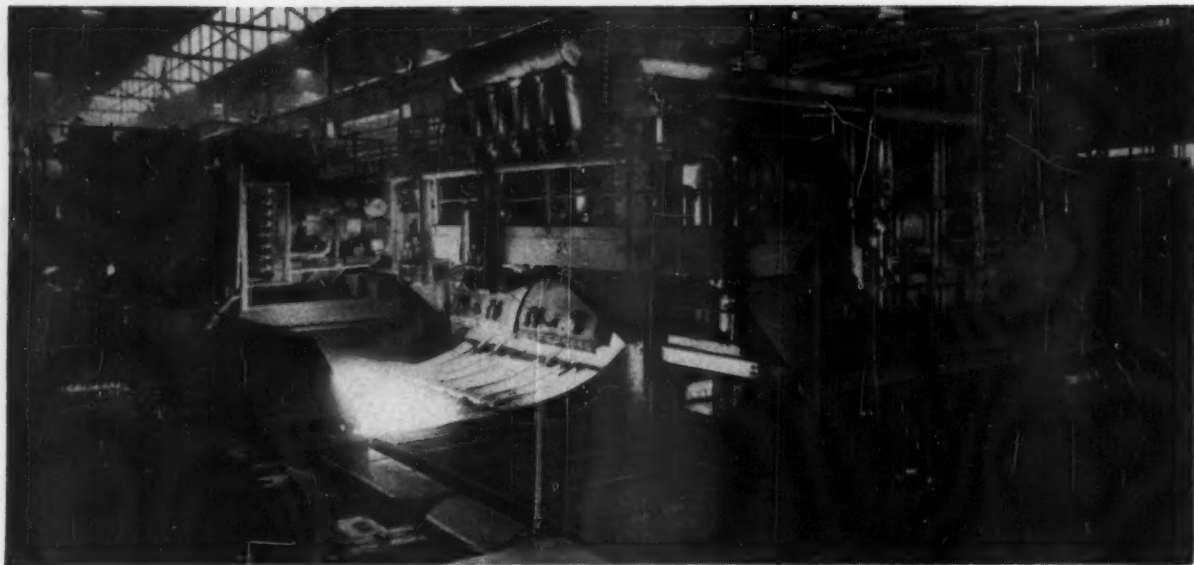


Fig. 1. A hot slab being ejected from the furnace on to the roller table.

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This glamour applies not only to Stainless Steel products, some of which are illustrated in this article,

but also to its processing. In fact, the ultimate durability of Stainless Steel depends upon a precise temperature/time heating and reheating schedule, which processes are usually carried out by town gas because of its inherent flexibility as a heating medium.

Fig. 1 shows a close-up view of a slab heating furnace at Shepcote Lane Rolling Mills Limited—a subsidiary company of Firth-Vickers Stainless Steels Limited, in which Samuel Fox & Co. Limited have a one-third interest. In the illustration a red hot slab has just been ejected on to the run-out table. This furnace heats

nine tons of slab hourly at a temperature of $1,230^{\circ}\text{C}$ before ejection, using 35,000 cubic feet of town gas per hour—each slab weighing approximately three tons.

The impressive machinery used to process Stainless Steel is shown in Fig. 2—the plant producing either matt or mirror-finished coiled strip. In the background are shown the gas-fired slab-heating furnace and the primary rolling section. The gas-fired coil reheating furnaces and the automatically controlled four-high finishing mill together with the run-out table are shown in the foreground.

Fig. 2. A general view of the hot mill bay showing furnaces, Steckel Mill and run-out table.

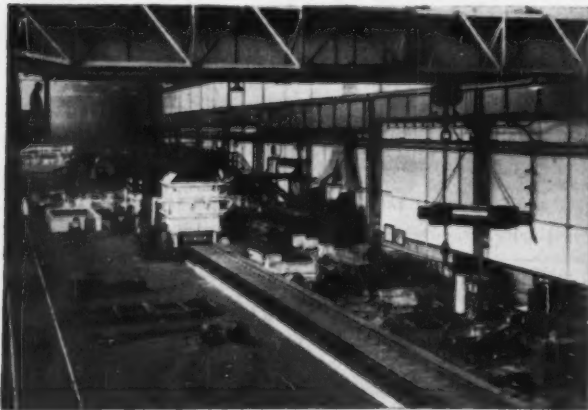


Fig. 3. The four-high hot Steckel Mill installed at Shepcote Lane Rolling Mills Limited.

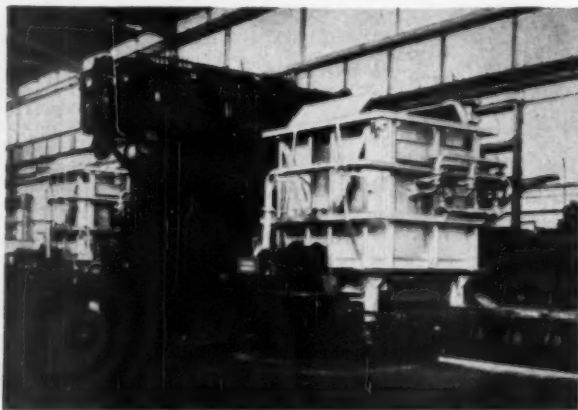


Fig. 3 shows the complex four-high Steckel Mill with its adjacent coil reheating furnaces. Each furnace is rated at 8,000 cubic feet per hour, and the plant will roll up to nine passes with a drop in temperature of the steel of only 250°C. The treatment of Stainless Steel is only one of thousands of different trades, professions and processes served by the Gas Industry. Each Area Gas Board has specialist staff familiar with the heating problems of these many industries. They all pool their ever-increasing knowledge through the Gas Council's Industrial Gas Development Committee, whilst the Industrial Gas Information Bureau keeps in touch with developments in gas-fired equipment in all parts of the world. Thus any user, or potential user, of gas-fired equipment has a fund of technical knowledge available to him by asking for the services of his Area Gas Board.



Fig. 4. A sterilising unit for surgical and dental instruments.

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Fig. 5. Receiving and storage tanks for margarine blends in the processing department of Van Den Berghs & Jurgens Ltd., Stork Margarine Works, Purfleet.



Fig. 6. The Wimpy, Lyon's Corner House, Coventry Street, London.

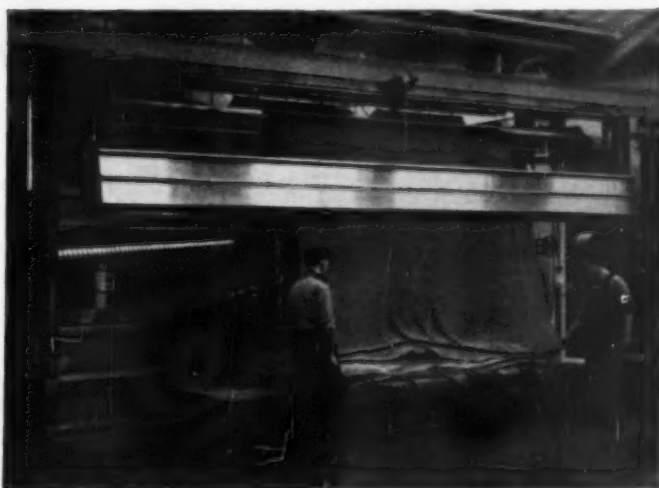
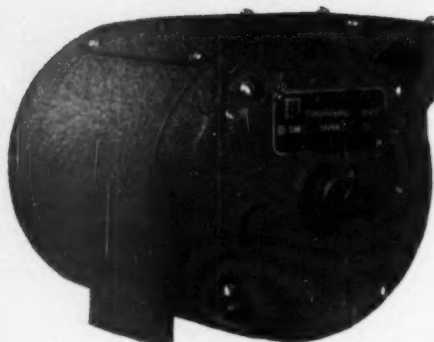


Fig. 7. The largest stainless steel carpet dyeing machine ever produced in Great Britain.

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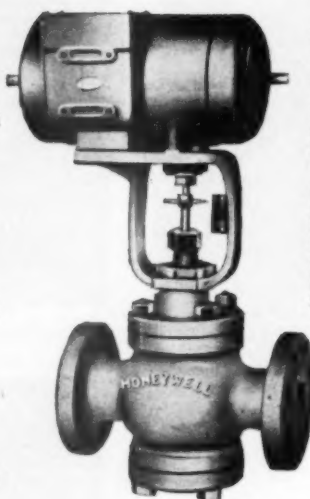
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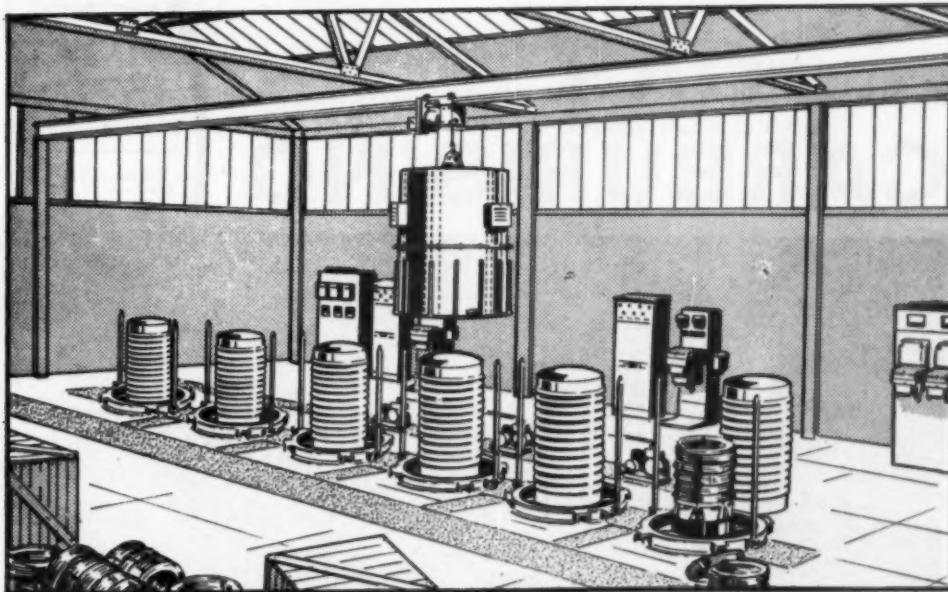
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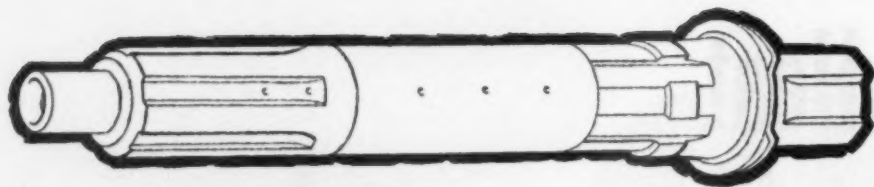
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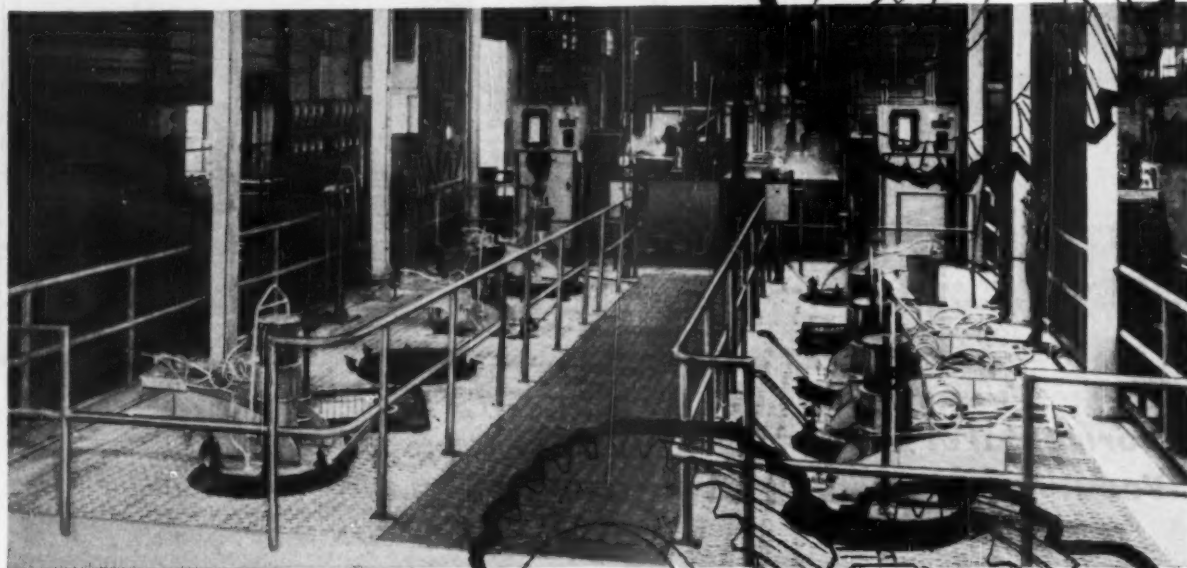
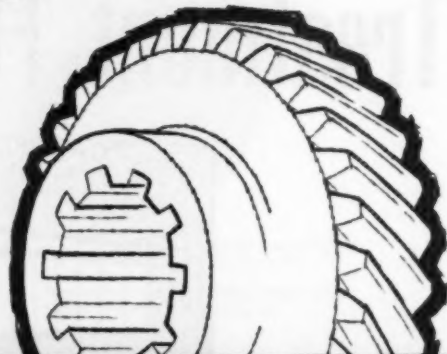
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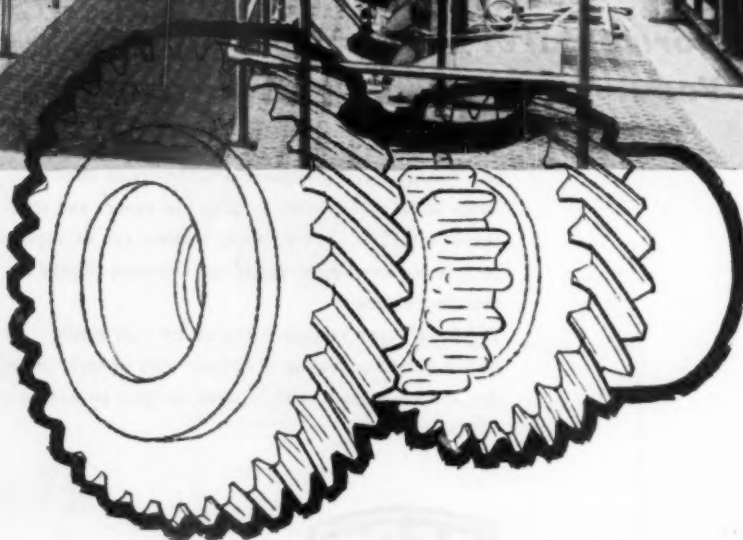
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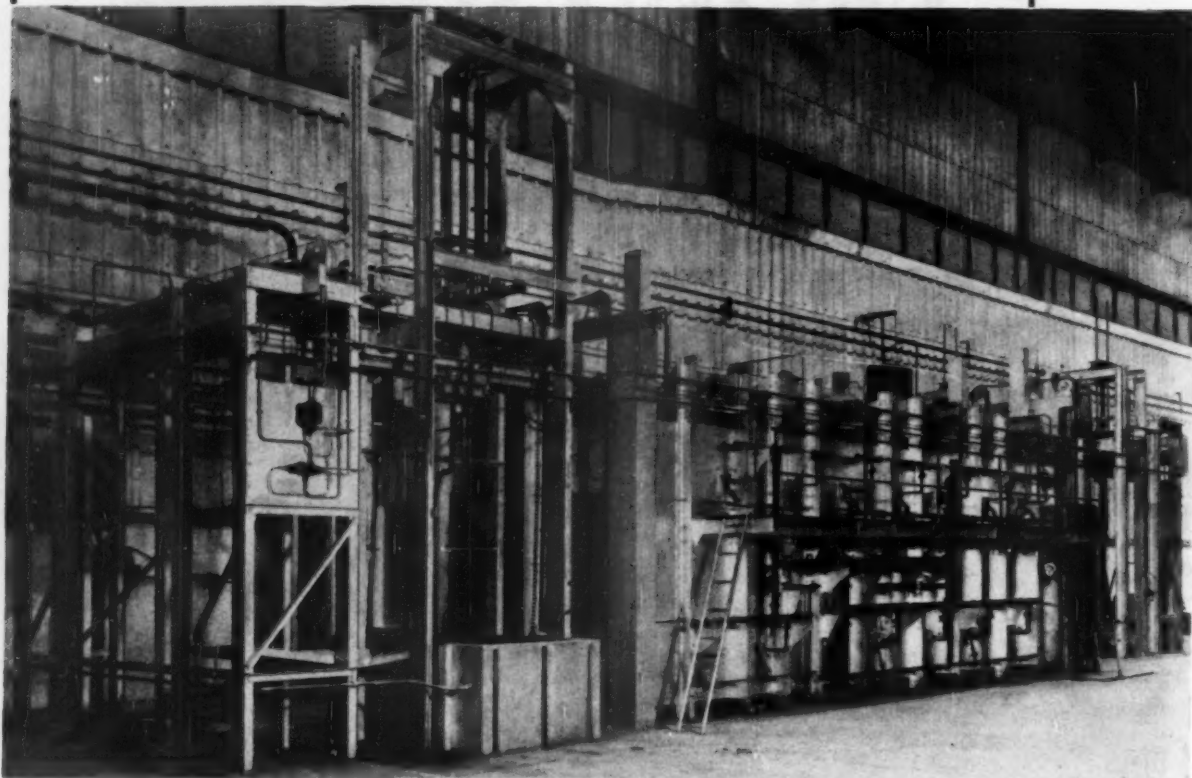
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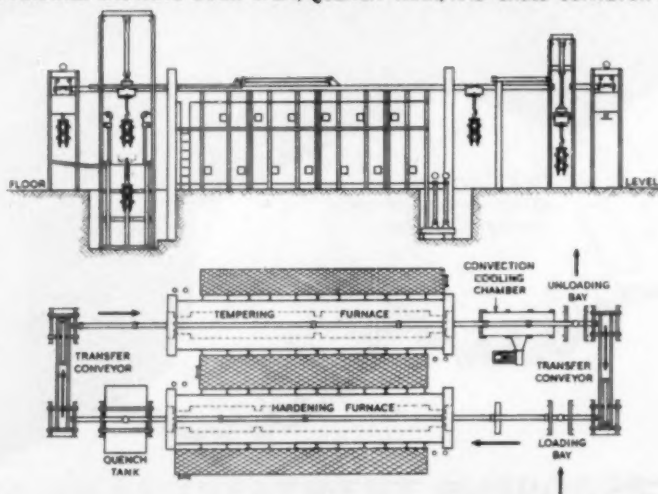
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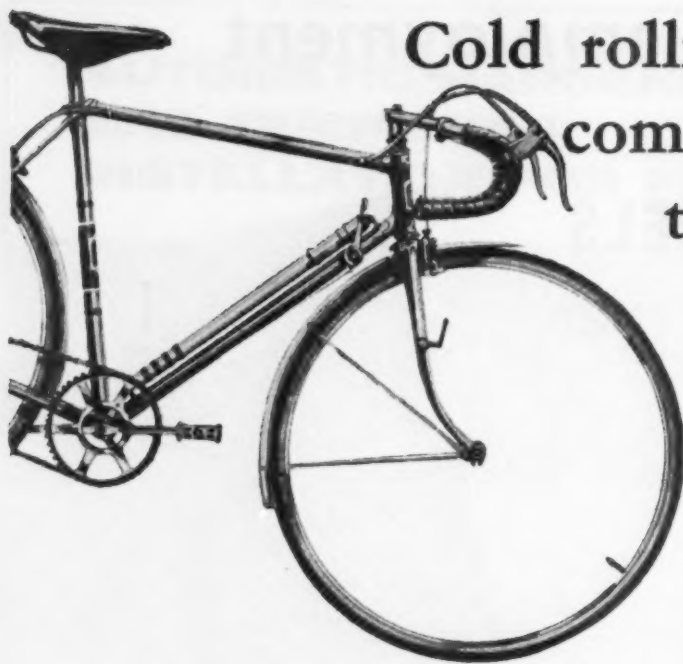
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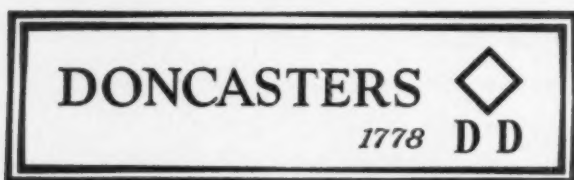
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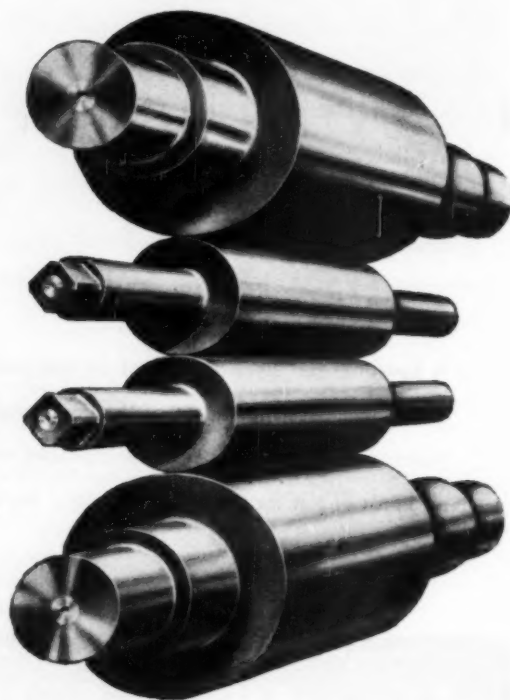
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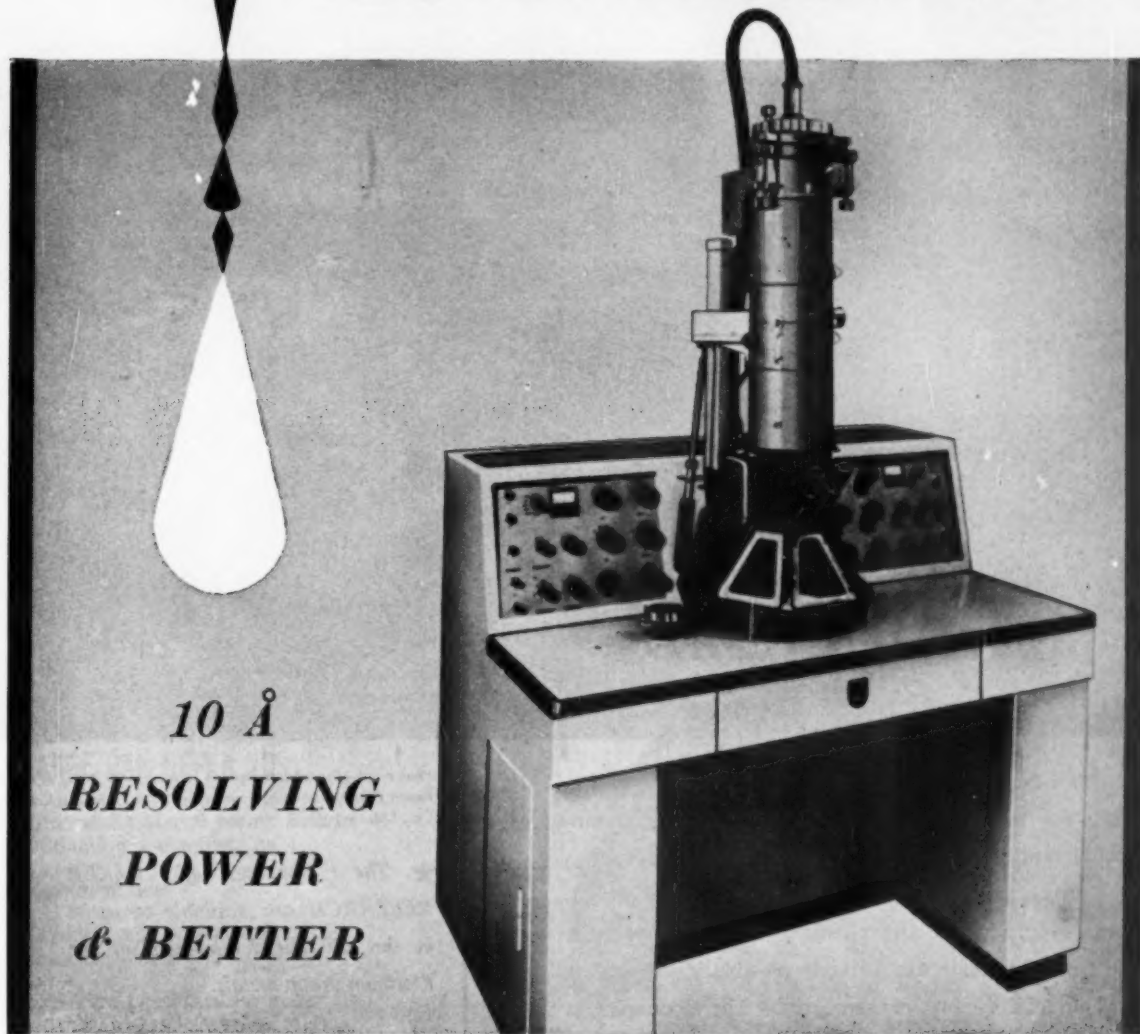
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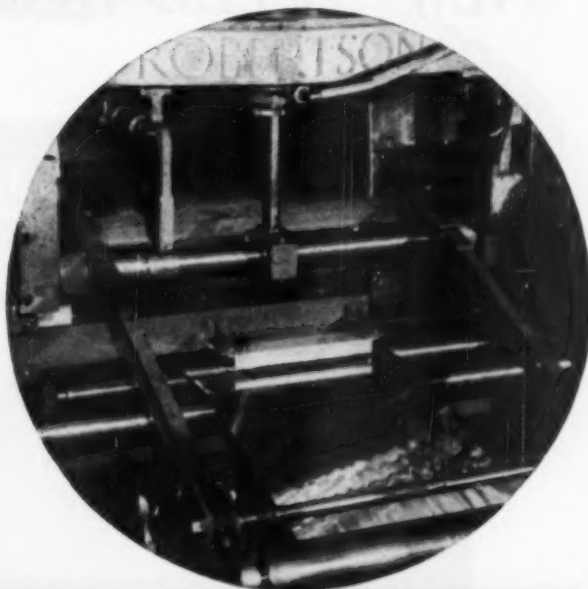
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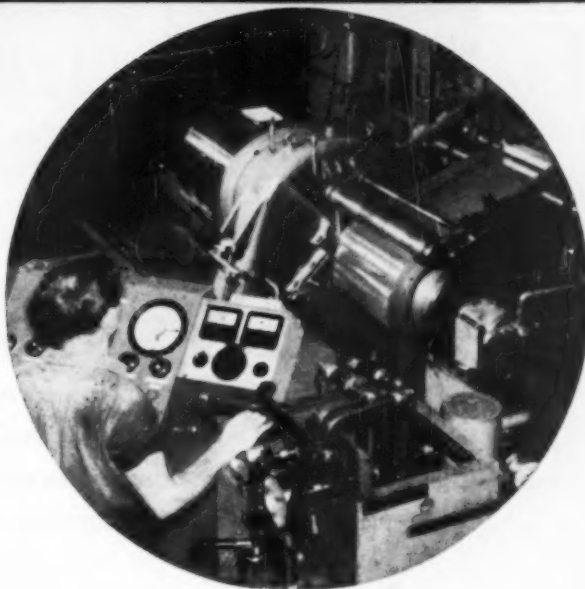
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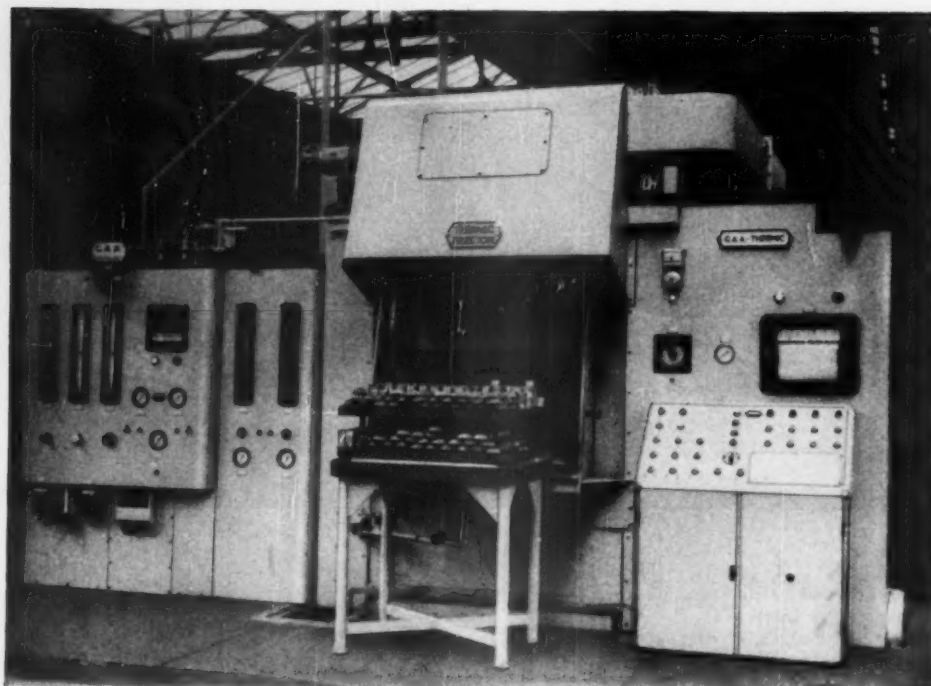
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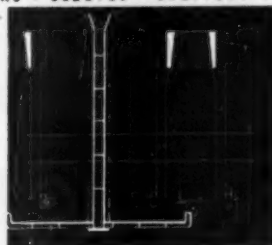
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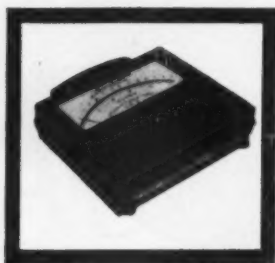
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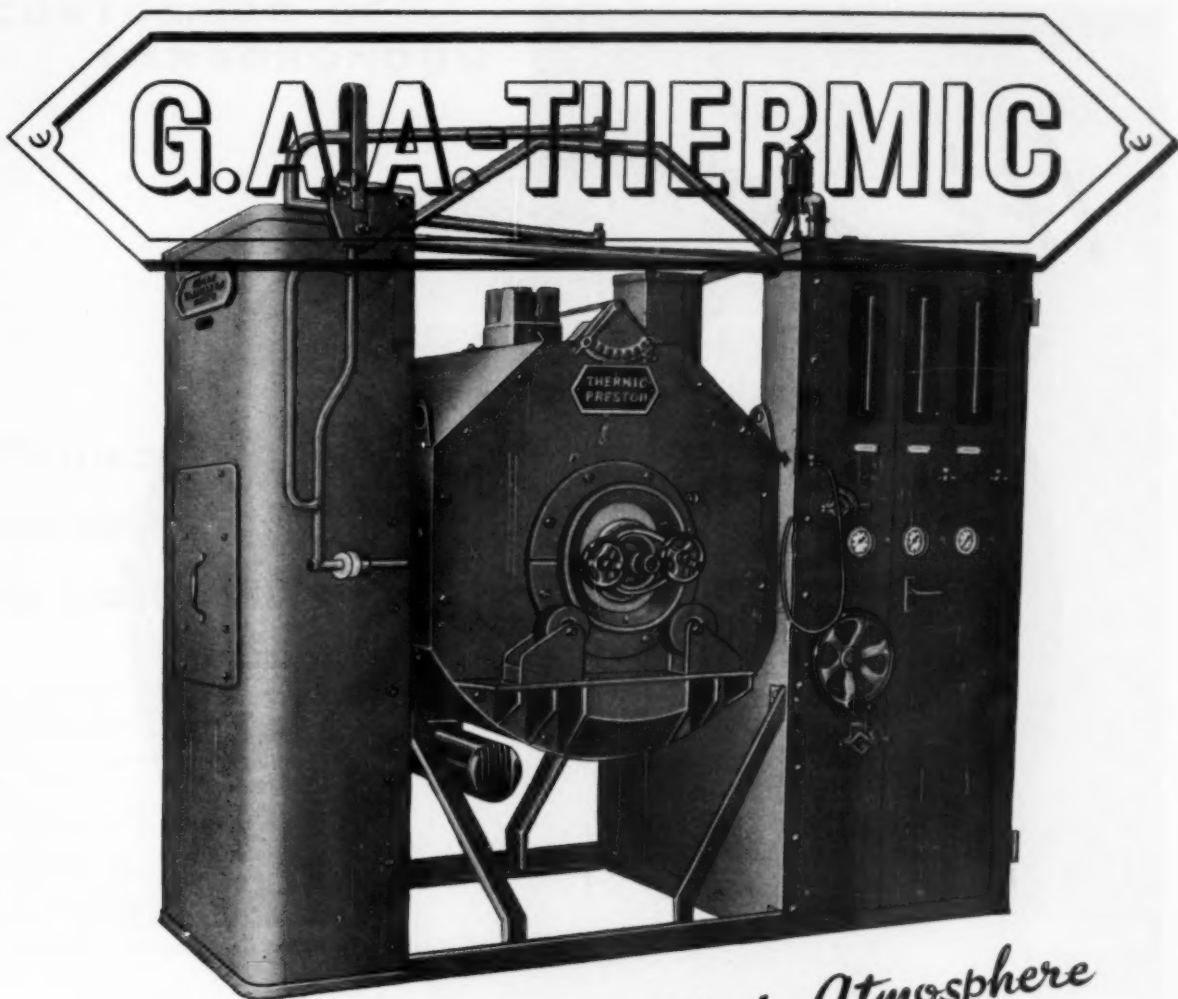
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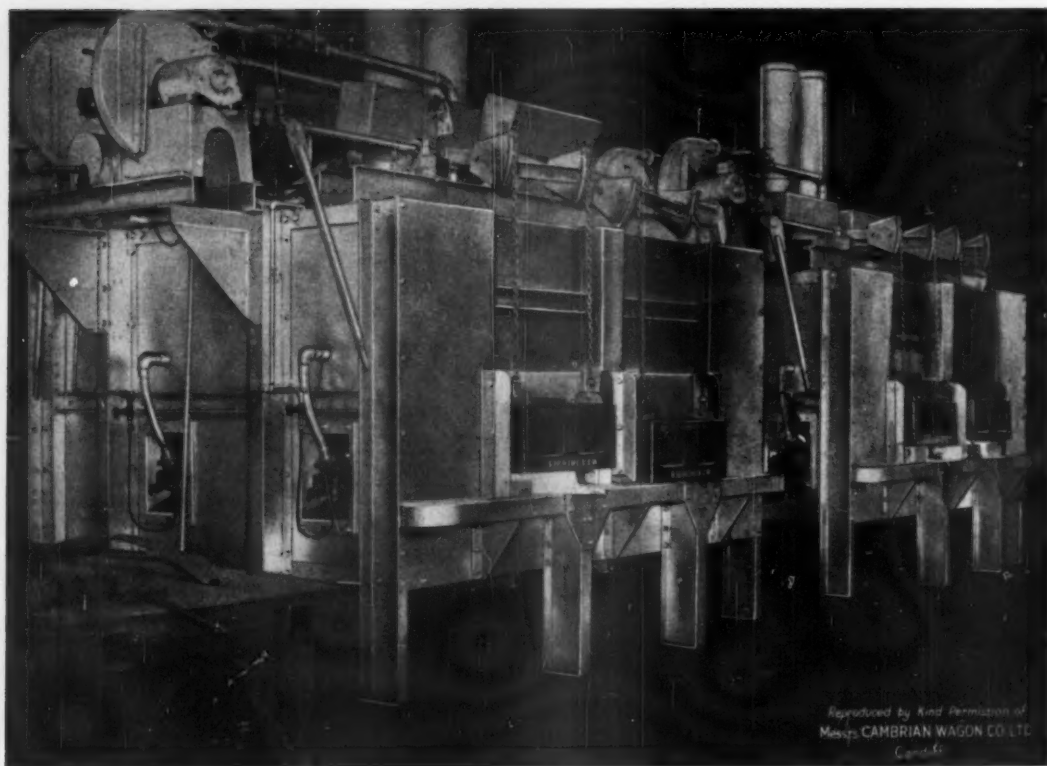
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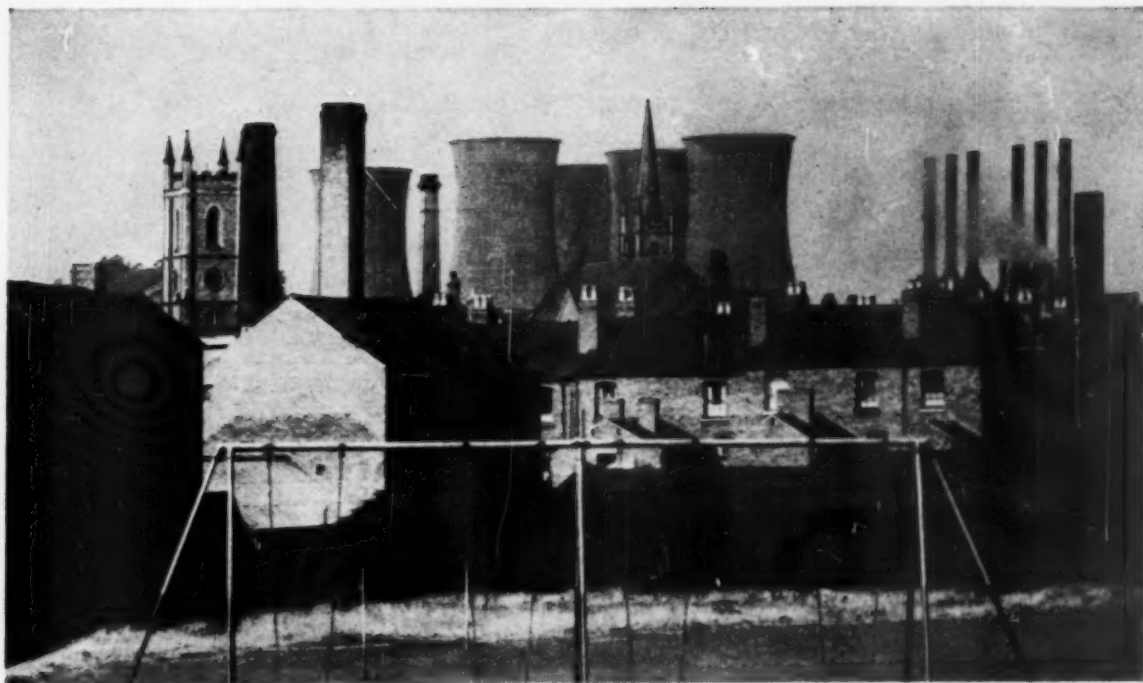
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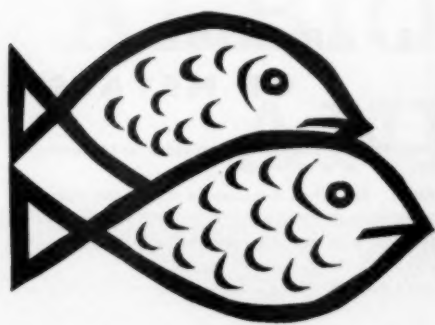


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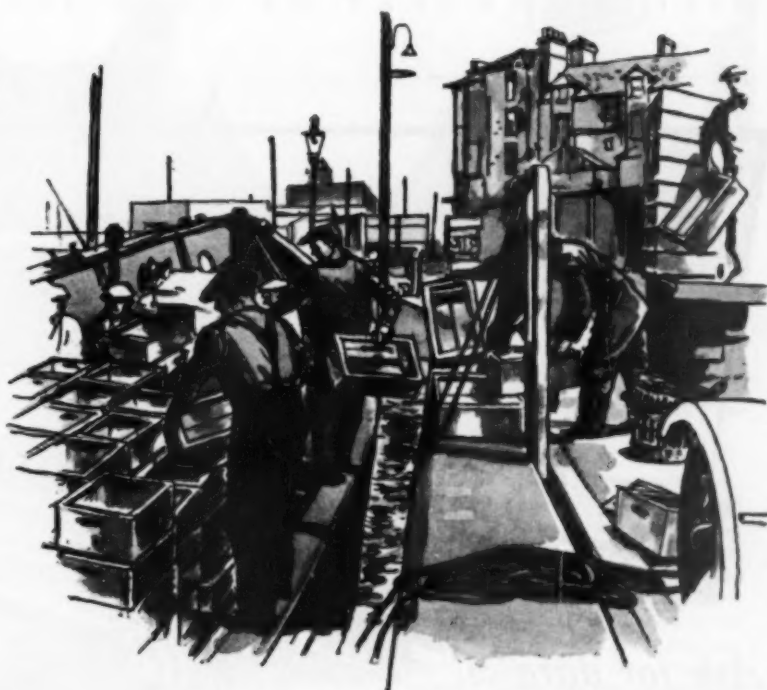


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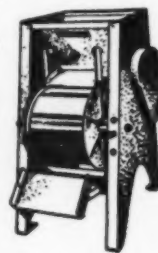
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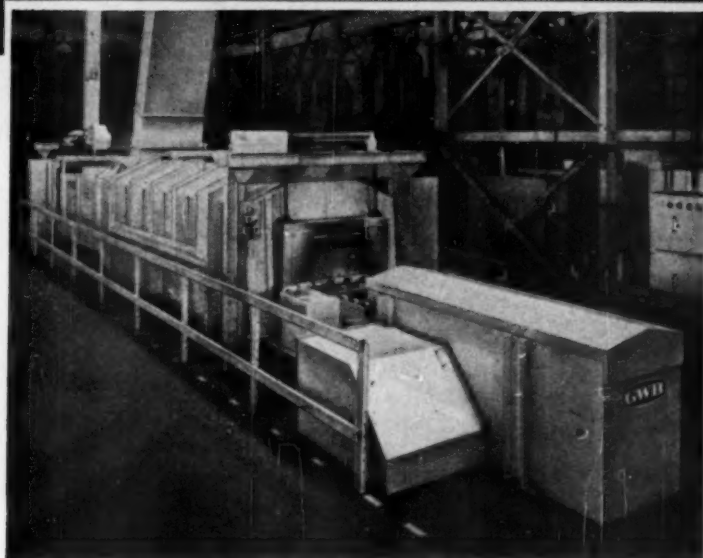
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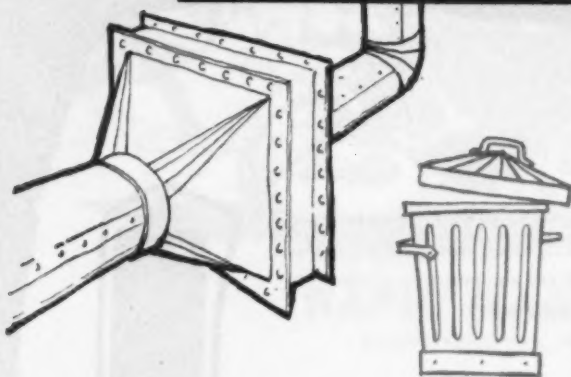
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METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

February, 1960

Vol. LXI. No. 364

Aluminium in World Trade

FOR some years it has been the practice to devote a considerable section of our February issue to the metal aluminium, a practice which is continued this year, when aspects such as enamelling, joining, and the hypereutectic aluminium-silicon alloys are featured, together with a survey of technical progress—as reflected in English language publications—during 1959. Today aluminium is one of the leading metals in the world's industrial society, being second only to steel in the volume produced. Because of this, it is not inappropriate that reference should be made here to the part aluminium is playing—and is likely to play—in world trade. The subject was the theme of a speech delivered recently by Mr. Nathaniel V. Davis, President of Aluminium, Ltd., at a meeting in Paris of the Chamber of Commerce France-Canada. After a brief introductory outline of the links between France and Canada in the aluminium field, Mr. Davis pointed out there are significant differences. Canada, even with one of the highest *per capita* consumption levels, consumes only 15% of its aluminium production, and has for many years served fabricators and manufacturers all over the world, whereas France, like many other countries, has developed her aluminium industry chiefly for national needs. Self-sufficiency in aluminium has been a matter of strategic national policy, but with the growing popularity of the metal for countless civilian applications, local production is inadequate in many countries, and imports have become an important source of the metal.

Mr. Davis continued: "We are, I believe, on the threshold of a new era in the industry. Today only about 20% of the aluminium produced in the free world enters into international trade, the balance of 80% being consumed in the producing country. But there are factors at work which are changing this. We are going to see more aluminium produced in the less industrialized areas of the world and shipped to the more advanced countries. This will result in greater movement of the metal in international trade; it will also have important political and sociological effects.

"Among the reasons for this fundamental change, there is first the fact that it is becoming more and more difficult to obtain the electric power for the production of aluminium within the industrialized and populated areas. The production of aluminium requires immense quantities of electric energy available on a constant basis and at prices considerably less than those paid by other manufacturing industries, by households or by other users.

"Another reason is that with aluminium consumption in the western world now at a level of over three million tons and promising to continue to expand to higher levels in the years ahead, the factor of transporting the raw materials for its production, principally the ore—bauxite—to the places where electric power is available

in sufficient quantities, increases in significance. Today only a small fraction of the many millions of tons of bauxite is made into metal at or near the bauxite mines, which are located mostly in the tropical, underdeveloped areas. We are already seeing a tendency to lessen the need for ships and port and railroad facilities by the location of the ore-processing plants—the alumina plants—near the bauxite mines rather than near the smelters. Our company has built two alumina plants in Jamaica and is building another in British Guiana, all three adjacent to the bauxite mines. Similarly, French and other interests are completing the construction of the first alumina plant in Africa at Fria, Guinea. In the same country our company has undertaken a similar project in Boké and is at present working on an international consortium, including French producers, for its realization. As this factor of transportation of raw materials becomes even more significant, there will undoubtedly be a tendency to place new aluminium production plants at locations where a satisfactory combination of large resources of bauxite and electric power can be found. The inevitable result of these changes will be a greater movement of aluminium ingot in international trade.

"One should, I suggest, see this as one aspect of the new conditions we are likely to experience in this decade, during which international trade will become increasingly important in supplying the needs of growing populations. In 1959 the total value of all international trade in the western world amounted to about 100 billion dollars. By 1970 this may increase to at least 150 billion dollars. In this expansion aluminium will be one of the products adding to the increase.

"A shift to more international trade in primary aluminium will, I think, inevitably require dismantling many of the measures used by countries to protect their local aluminium industries. Such a process is of course contemplated within the regional trade blocs being established in Europe. A similar process has also been under way in the United States and Canada since before the last war. An excellent opportunity for freeing world trade in aluminium from the accumulated restrictions is offered in the emergence of the Common Market, in which the widely different tariffs of the individual countries are to be made into a single common external tariff. If the decision is to select a low rate, there will be freedom for industries and manufacturers of goods in the Common Market to buy their basic raw materials as they wish. They will consequently be on a more competitive basis with the manufacturers in other areas and also able to meet the expanding requirements of the Common Market itself. I am sure you would agree that the interests of these users of aluminium in Europe deserve the most attention in setting the rules of trade with other areas, for it is they who will decide whether to use aluminium or some other material. Even today more than one fifth of the supply of aluminium for the Common Market

area comes from outside, mostly from Canada and Norway."

"The large increase in demand which we foresee leads us to conclude that Common Market countries will have to look more and more outside their borders for some of the aluminium supplies their industries will require. In the immediate future both Canada and Norway offer capacity, both developed and in process of developing, which should meet the growing needs of the area. Looking beyond the immediate future, however, new sources of production will have to be developed."

"A great deal of attention is being given to the often discussed projects in the newly emerging nations of Africa. There are also possibilities of large-scale aluminium production in other areas such as Australasia and parts of South America, as well as North America. In fact, a list of possible projects with underdeveloped electric power potentials throughout the free world amounts to about 6,000,000 tons. While the potential projects in the remote areas of the world will, by their very nature, require many years to bring into production and tremendous capital expenditures, the interim needs

can, we believe, be adequately met from existing sources."

"In suggesting that these interim needs can be well served from existing sources, such as Canada, and that trade barriers should be reduced to the minimum to permit maximum growth, I recognize the possibility of appearing to speak only from self-interest—and without regard for the position of others. Some people may say, for example, that the aluminium producing companies of Europe will need protection from the larger enterprises elsewhere. This does not give proper credit to the firm preferential position these companies have in their home countries, being well integrated on the fabricating side and possessing large resources in fields other than aluminium. Nor does it give credit to the ability they have demonstrated as competitors in world markets."

Mr. Davis concluded: "I have spoken at some length on our views of the changing character of international trade in aluminium and for the consequent desirability of removing trade barriers. In short, we stand for free trade in aluminium in the western world. We believe this is the best course for the western world to take in this metal which is growing in acceptance everywhere."

Meeting Diary

22nd March

Institute of Fuel, Scottish Section. Annual General Meeting, and "Electro Precipitators," by J. MARTIN and J. E. SAYERS. Royal College of Science and Technology, Glasgow. A.G.M. 6 p.m.; Lecture 7 p.m.

Sheffield Metallurgical Association. "Problems and Progress in the Analysis of Slags and Refractories," by D. SHIREBY. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

23rd March

Institute of British Foundrymen, London Branch. "Review of the Work of the I.B.F. Technical Council on the Effect of Cooling Rate on the Properties of Grey-Iron Castings," by M. M. HALLETT. Constitutional Club, Northumberland Avenue, London, W.C.2. 7.30 p.m.

Institute of British Foundrymen, Southampton Section. "The Buehrer Automatic Moulding Plant," by C. ZERNER. Illustrated with film. Technical College, St. Mary's Street, Southampton, 7.30 p.m.

Institute of Welding, Medway Section. "Developments in Automatic Welding," by A. M. HORSFIELD. Sun Hotel, Chatham. 7.30 p.m.

24th March

Institute of Metals, Sheffield Local Section. "Molybdenum," by DR. L. NORTHCOTT. Applied Science Building, The University, St. George's Square, Sheffield. 7.30 p.m.

29th March

Institute of British Foundrymen, Slough Section. Annual General Meeting, followed by paper on "The New Metals," by J. R. CRANE. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Sheffield Metallurgical Association. "Corrosion—the £600 Million Problem," by A. M. EDWARDS. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

29th to 31st March

Institute of Metals. Spring Meeting. Church House, Great Smith Street, London, S.W.1. Further details will be found on page 85.

31st March

Institute of Plant Engineers, North East Branch. "Type and Application of Plant for Open-Cast Coal Extraction," by H. BRIGGS. The Three Tuns Hotel, Durham City. 7 p.m.

Southampton Metallurgical Society. Annual General Meeting, followed by "Stress-Corrosion," by DR. H. K. FARMERY. Engineering Block, Southampton University. 7.15 p.m.

1st April

Institute of Fuel, South Wales Section. "The Benson Boiler." Four papers by staff of THE STEEL COMPANY OF WALES. South Wales Institute of Engineers, Park Place, Cardiff. 6 p.m.

5th April

Institute of Metals, Oxford Local Section. Annual General Meeting, followed by "Low Temperature Properties of Metals," by H. M. ROSENBERG. Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

Institute of Welding, Slough Section. "Shop Inspection of Welds." Lecture Hall, Community Centre, Farnham Road, Slough. 7.30 p.m.

6th April

Society of Chemical Industry, Corrosion Group. Spring Lecture. "The Presentation of Corrosion Information," by DR. J. W. JENKIN. 14, Belgrave Square, London, S.W.1. 6 p.m.

7th April

Institute of Metals, London Local Section. Annual General Meeting followed by a Symposium on "Metallographic Techniques." 17, Belgrave Square, London, S.W.1. 6 p.m.

Leeds Metallurgical Society. "Metallurgical Research in the Department of Scientific and Industrial Research," by DR. N. P. ALLEN. Arrangements to be announced.

Liverpool Metallurgical Society. "The Examination of Irradiated Fuel Elements," by DR. G. B. GREENOUGH, followed by 12th Annual Meeting. Library, Dept. of Metallurgy of the University of Liverpool, 146, Brownlow Hill, Liverpool, 3. 7 p.m.

8th April

West of Scotland Iron and Steel Institute. Annual General Meeting. Short Papers on "Mill Operation," by T. HARRIS, G. STEEL and J. CRAIG. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

11th April

Institute of British Foundrymen, East Anglian Section. Annual General Meeting, followed by paper on "An Introduction to Patternmaking in Plastics," by H. G. C. KING. Lecture Hall, Public Library, Ipswich. 7.30 p.m.

12th April

Powder Metallurgy Joint Group of the Iron and Steel Institute and the Institute of Metals. Symposium on "Continuous Processing in Powder Metallurgy." See page 86.

The Creep Strength of some High Temperature Alloys at 1,050°—1,200°C.

By H. C. Child, B.Sc., A.I.M., A. B. Collier, and C. F. West

Research Department, Jessop-Saville, Ltd.

Considerable use has been made of austenitic steels as furnace parts and heat treatment jigs, but information on their mechanical properties has, in the main, been limited to the results of stress-rupture tests at temperatures up to 1,000° C., where no extensometry problems are encountered. In the present series of creep tests on cast and wrought austenitic steels at 1,050–1,200° C., these problems have been overcome by the use of a cantilever specimen.

Introduction

ALTHOUGH the creep properties of austenitic steels and nickel- and cobalt-base alloys have been exhaustively studied in recent years, there has been little or no information published on the creep properties at temperatures above 1,000° C. This is partly because there is little commercial use made of these alloys at these very high temperatures, but it is also partly due to the difficulty of carrying out such tests.

As the jet engine has been further developed, gas temperatures have risen, and today, such parts as turbine stator blades are operating at temperatures of at least 1,100° C., and perhaps higher. Even turbine rotor blades are now running as high as 950° C. Accordingly, a limited amount of data is now available at temperatures up to 1,000° C.^{1,2} In the main, this data is confined to stress rupture properties, which are relatively easy to determine as there are no extensometry problems.

Considerable use has, of course, been made of austenitic steels at temperatures above 1,000° C. in the construction of furnace parts and jigs for heat treatment operations. These applications mainly involve ability to resist atmospheric oxidation, although a certain amount of load carrying capacity is required. Presumably, the designers of such equipment have so far resorted mainly to *ad hoc* methods of design based on the effectiveness of previous components in service.

The authors decided to carry out a survey of some typical wrought and cast austenitic alloys to assess their potentialities in the temperature range 1,050°–1,200° C. A form of creep testing where the specimen is bent as a cantilever^{3,4} was chosen, as there is considerable difficulty in extensometry for tensile testing at these high temperatures.

Procedure

Creep tests of durations up to approximately 1,000 hours and strains of up to 1% have been carried out on the series of alloys detailed in Table I.

Where the material has had adequate oxidation resistance, the tests have been carried out in air, using the cantilever bending method. In cases where the oxidation resistance was inadequate, the tests have been carried out in an atmosphere of static argon using cantilever bending. The equipment and the test technique used for the inert atmosphere testing has been previously described.⁴

Results

Typical creep curves obtained with the cast nickel-base material, G.39, are shown in Figs. 1 and 2 for testing temperatures of 1,100° C. and 1,200° C., respectively. From graphs such as these, the data shown in Figs. 3 and 4 were derived, indicating the time for different total plastic strains at various stress levels.

TABLE I.—CHEMICAL SPECIFICATIONS OF THE ALLOYS STUDIED

Quality	Chemical Specification (%)														
	C	Mn	Si	Ni	Cr	W	V	Mo	Co	Fe	Ti	Cu	Al	Nb	Ta
R.39	0.12	0.6	0.9	0.4 max.	21.0	—	—	0.45	—	Bal.	0.35	—	—	—	—
R.12	0.2 max.	0.55	1.25	1.25	27.0	0.4	—	0.7	—	Bal.	0.4	—	—	—	—
R.22	0.21	0.9	1.0	14.0	21.0	2.8	—	—	—	—	—	—	—	—	—
R.40	0.21	0.8	1.0	11.5	22.5	1.0	—	—	—	Bal.	—	—	—	—	—
R.23	0.12	1.1	1.75	22.5	25.5	—	—	—	—	Bal.	—	—	—	—	—
R.13	0.8 max.	0.5	1.75	61.0	16.5	—	—	—	—	—	—	—	—	—	—
G.39	0.5	1.0	1.0	60.0	20.0	3.0	—	3.0	—	Bal.	—	—	—	1.5	1.5
Nimonic 75	0.12	1.0 max.	1.0 max.	Bal.	19.5	—	—	—	—	5.0 max.	0.4	0.5 max.	—	—	—
Nimonic 80	0.1 max.	1.0 max.	1.0 max.	Bal.	19.5	—	—	—	2.0 max.	5.0 max.	2.2	—	1.2	—	—
Nimonic 90	0.1 max.	1.0 max.	1.5 max.	Bal.	19.5	—	—	—	18.0	5.0 max.	2.2	—	1.4	—	—
G.19	0.4	0.6	1.0	13.0	19.0	2.5	—	2.0	10.0	—	—	—	—	3.0	—
G.42B	0.25	1.0	0.40	15.0	19.5	2.2	2.2	2.3	25.0	—	0.85	—	—	2.2	—
G.32	0.3	0.8	0.5	12.5	19.0	—	2.8	2.0	45.0	—	—	—	—	1.3	—

TABLE II.—CREEP STRENGTH OF ALLOYS AT 1,050° C.

Quality	Condition	"K" Used	Stress (lb./sq. in.) to Cause Indicated Plastic Strain in Stated Time															
			30 hours				100 hours				300 hours				1,000 hours			
			0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%
R.29	Wrought	0-69	170	224	300	—	93	148	235	296	—	99	142	192	—	—	(88)	93
R.29	Cast	0-74	—	294	476	(681)	—	170	288	464	—	—	165	258	—	—	(98)	138
R.12	Wrought	0-64	—	220	373	434	—	108	266	360	—	—	140	246	—	—	(53)	113
R.12	Cast	0-82	143	300	637	740	—	104	332	592	—	—	(101)	299	—	—	—	(68)

Figures in parentheses are extrapolated values

TABLE III.—CREEP STRENGTH OF ALLOYS AT 1,100° C.

Quality	Condition	Atmosphere	"K" Used	Stress (lb./sq. in.) to Cause Indicated Plastic Strain in Stated Time															
				30 hours				100 hours				300 hours				1,000 hours			
				0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%
R.22	Wrought	Air	0-87	—	—	207	297	—	—	—	127	—	—	—	—	—	—	—	—
R.22	Cast	Air	0-65	268	691	—	—	83	485	(855)	(1020)	—	310	567	722	—	(134)	238	372
R.40	Wrought	Air	0-73	34	43	87	107	—	32	58	88	—	—	37	53	—	—	—	38
R.23	Wrought	Air	0-68	145	183	238	308	127	151	200	270	(119)	127	151	205	—	119	(140)	(167)
R.23	Cast	Air	0-79	(450)	652	825	915	(400)	502	602	740	—	356	470	526	—	—	(326)	344
R.13	Cast	Air	0-75	525	668	963	1080	440	525	773	893	—	428	533	715	—	—	(405)	453
G.39	Cast	Air	0-67	1640	3120	3760	—	1360	1700	2220	2480	1140	1380	1720	2000	(560)	(1130)	1300	1440
Nimonic 75	Cast	Air	0-73	428	718	985	1053	334	417	753	938	—	312	417	567	—	—	324	359
Nimonic 80	Wrought	Air	0-76	175	223	404	585	—	140	232	388	—	(113)	147	260	—	—	(107)	147
Nimonic 80	Cast	Air	0-73	255	475	880	1010	—	336	534	800	—	235	360	545	—	—	802	260
Nimonic 90	Cast	Air	0-74	445	610	925	1140	335	433	658	930	305	340	500	586	—	305	287	435
G.32	Wrought	Argon	0-82	124	178	248	(294)	(32)	117	182	240	—	(39)	117	182	—	—	(59)	(98)
G.42B	Wrought	Argon	0-85	358	535	—	—	230	400	590	—	(135)	278	470	605	—	(163)	(337)	(470)
G.19	Wrought	Argon	0-63	—	—	—	(120)	—	—	—	—	—	—	—	—	—	—	—	—

Figures in parentheses are extrapolated values

TABLE IV.—CREEP STRENGTH OF ALLOYS AT 1,200° C.

Quality	Condition	° K ° Used	Stress (lb./sq. in.) to Cause Indicated Plastic Strain in Stated Time															
			30 hours				100 hours				300 hours				1,000 hours			
			0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%	0-1%	0-2%	0-5%	1-0%
R.12	Cast	0-76	(33)	40	118	125	—	—	68	93	—	—	39	62	—	—	—	39
R.23	Wrought	0-74	—	88	170	276	—	—	106	158	—	—	—	103	—	—	—	(94)
R.23	Cast	0-76	—	—	241	338	—	—	132	210	—	—	—	(90)	—	—	—	—
R.13	Cast	0-89	268	595	780	820	120	219	650	750	—	106	226	432	—	—	85	120
G.39	Cast	0-67	—	400	770	995	—	—	460	670	—	—	—	380	—	—	—	—
Nimonic 75	Cast	0-77	171	226	478	550	—	171	208	422	—	—	177	202	—	—	—	169
Nimonic 80	Wrought	0-77	(90)	94	228	330	—	89	95	137	—	(87)	92	94	—	—	—	92

Figures in parentheses are extrapolated values

To illustrate the use of the inert atmosphere testing unit, similar data at 1,100° C. for a wrought iron-base alloy, G.42B, is shown in Figs. 5 and 6.

From similar results obtained from tests at various temperatures on the other alloys, Tables II, III and IV have been derived. These summarise the creep strengths of the various alloys at temperatures of 1,050° C., 1,100° C. and 1,200° C.

It will be noted that mention is made of a cantilever creep parameter *K*. This has been described in detail in an earlier paper⁴ and relates the stresses present in a beam subject to bending according to elastic theory to those actually occurring under creep conditions.

Discussion of Results

To facilitate a general comparison of the creep properties of the various alloys investigated, the creep strength for one of the criteria, 1% plastic strain in 100 hours, given in the Tables, is shown graphically in Fig. 7.

It will be seen that all the alloys show a rather similar fall-off in strength with temperature. It is interesting to note that the cast alloys are in general very much more creep resistant than their wrought equivalents. It has been known for some time that when testing temperatures are raised cast materials tend to show better creep and rupture properties. At 1,100° C. and above,

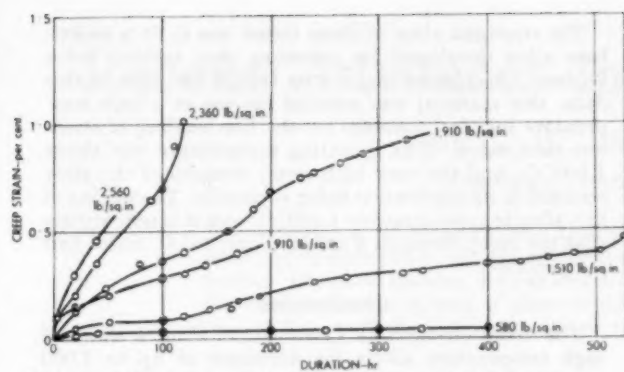


Fig. 1.—Creep curves for cast G.39 material at 1,100° C. $K = 0.67$.

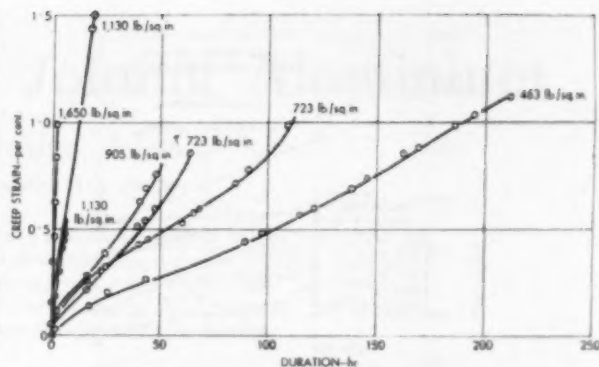


Fig. 2.—Creep curves for cast G.39 material at 1,200° C. $K = 0.67$.

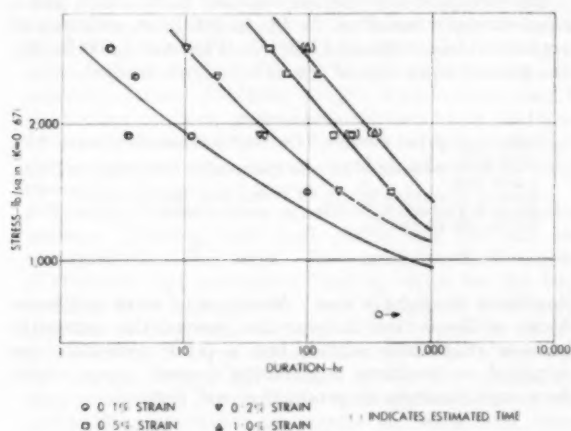


Fig. 3.—Stress-time curves for cast G.39 material at 1,100° C.

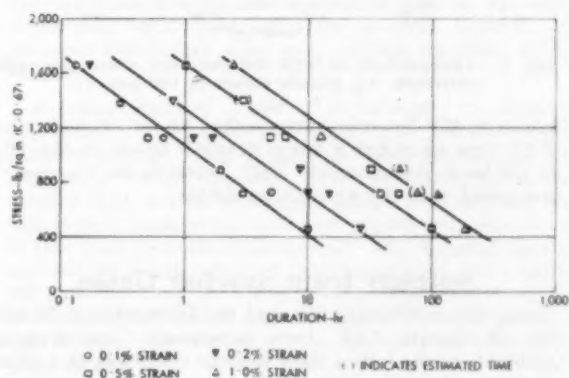


Fig. 4.—Stress-time curves for cast G.39 material at 1,200° C.

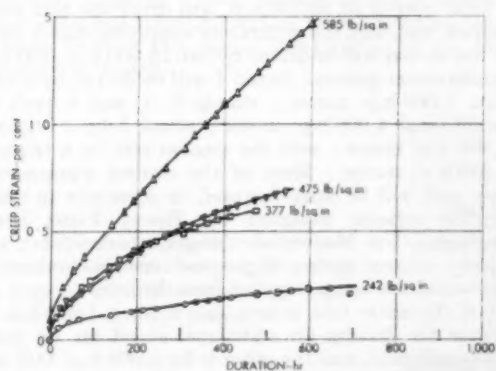


Fig. 5.—Creep curves for G.42B material at 1,100° C. in static argon. $K = 0.85$.

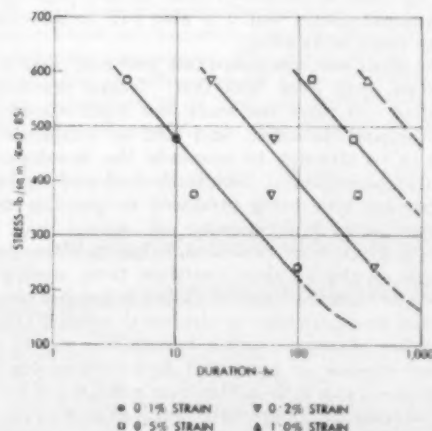


Fig. 6.—Stress-time curves for G.42B material at 1,100° C. in static argon.

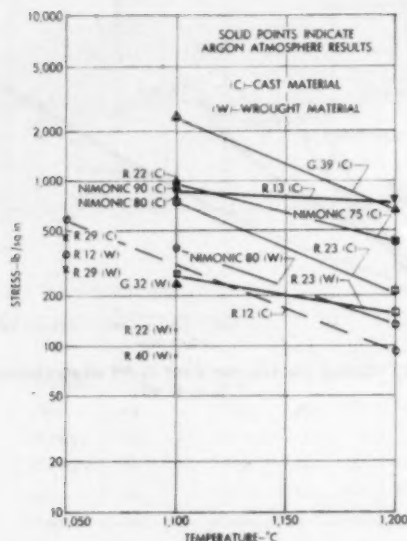


Fig. 7.—Comparison of high temperature creep strength (criterion 1% plastic strain in 100 hours).

however, this becomes very marked as, for example, the R.22 type alloy has a creep strength based on the 1% in 100 hours criterion over 700% better in the "as cast" compared with the wrought condition.

Sulphur from Smelter Gases

TEXAS GULF SULPHUR Co. and the International Nickel Co. of Canada, Ltd., have announced "encouraging results" in the initial eight-months operation of a pilot plant for obtaining pure sulphur from sulphur dioxide in the high quality roaster off-gas at Inco's large iron ore recovery operation in the Sudbury District of Ontario. Nearness to the Great Lakes offers Sudbury sulphur the advantage of low-cost transportation to eastern Canada and other large consuming areas. Feasibility of large tonnage commercial production will be determined in part by costs as projected from further pilot operations, the announcement said: it also will be affected by the future price of sulphur.

The plant was completed last year and, with associated facilities, cost over \$500,000. Initial operations consisted of test runs, but since last April operations have been around-the-clock, and will be continued on this basis in an attempt to conclude the development programme successfully. Sulphuric acid and liquid sulphur dioxide are now being produced in quantity from Inco smelter gases but, because of storage and shipping limitations on these products, it has not been possible to market all the sulphur available from such gases. In the event that the sulphur values in smelter gases can be reduced economically to elemental sulphur, the utmost flexibility of storage and transportation will be achieved.

The sulphur is extracted by reacting high quality sulphurous gas with a chemical reducing agent at high temperature over a specially developed catalyst. Among the three satisfactory reducing agents, natural gas (now available at Copper Cliff) has some technical advantage over propane gas or fuel oil, but selection will remain

The strongest alloy of those tested was G.39, a nickel-base alloy developed for precision cast turbine rotor blades. It is interesting to note that in the light of this data, this material was selected for use as a high temperature mandrel material for the hot bending of stainless steel tubes. The operating temperature was above 1,100° C., and the very high creep strength of the alloy resulted in its application being successful. The solidus of this alloy is approximately 1,240° C., and it is noteworthy that the creep strength is so high, even 40° C. below this temperature.

Conclusions

The creep strength at 1,050–1,200° C. of a series of high temperature alloys for durations of up to 1,000 hours and for strains up to 1% are recorded. In certain instances, the properties of wrought and cast materials have been compared, and it has been shown that the cast alloys may show an improvement in terms of stress within the range 50–700%.

The strongest alloy tested was cast G.39, which had a creep strength based on the 1% in 100 hours criterion of approximately 1 ton at 1,100° C. This was 1,400 lb./sq. in., greater than any of the other alloys studied.

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- 2 Wood, D. B. and Gregg, J. F., *Metal Treatment and Drop Forging*, 24 (143), August, 1958.
- 3 Harris, G. T. and Child, H. C., *J.I.S.I.*, 1950, June, 105, (2), 139-144.
- 4 Harris, G. T., Child, H. C., Collier, A. B. and West, C. F., *J.I.S.I.*, 1958, October, 100, (2), 136-143.

flexible in the light of cost. Many years' work in laboratories of Texas Gulf Sulphur had proved the extractive process chemically sound, but a pilot operation was required to evaluate engineering aspects upon which economic commercial production will depend.

Rolling Mill Orders from Australia

ORDERS worth nearly £700,000 for electrical equipment for Australian rolling mills have been obtained by A.E.I. Heavy Plant Division, Rugby, from Australian Electrical Industries Pty., Ltd. The largest order is for drives for a new 5-stand tandem cold strip mill which will roll wide strip at a maximum speed of 5,000 ft./min. Motors with a total output of 20,750 h.p. will drive the mill and its tension reel, and the generators supplying direct current to the motors will be driven by two 10,000 h.p., 750 r.p.m. synchronous motors. Stand 1 will be driven by a single-unit 2,000 h.p. motor; stands 2, 3, and 4 each by a double-unit 4,000 h.p. motor; stand 5 by a triple-unit 5,500 h.p. motor; and the tension reel by a triple-unit 1,250 h.p. motor. Most of the control equipment for this mill will be manufactured in Australia to suit the control scheme designed by Heavy Plant Division engineers, but Magnestats (magnetic amplifiers), supervisory control panel, high-speed circuit-breakers, and rheostats are being supplied from Britain.

Of the other two orders, one is for a 1,000 h.p. D.C. motor for driving an additional stand for an existing merchant mill, and the other is for a 500 h.p. D.C. motor with grid-controlled mercury-arc rectifier, to drive an edger stand which is being added to an existing billet mill.

Recent Advances in Joining Aluminium

By G. W. Eldridge, A.I.M.

Aluminium Development Association

After referring to recent outstanding examples of the use of welding in the fabrication of structures in aluminium, the author discusses developments in fusion welding, resistance welding, ultrasonic welding, brazing and soldering in the aluminium field. Reference is also made to the development of alloys suitable for joining by these processes, and to other methods of joining such as riveting and adhesive bonding.

ON November 3rd, 1959, the 40,000-ton liner *Oriana* was launched at the Barrow shipyard of Vickers Armstrong (Shipbuilders), Ltd., and next month (March) a further passenger vessel—the *Canberra*—is to be launched at the Belfast yard of Harland and Wolff, Ltd. These two ships, built for two major operating companies—the Orient and P. & O. lines, respectively—have in common at least one important feature that is of metallurgical interest: both have welded aluminium superstructures. The total weight of aluminium used in the *Oriana* has been quoted as 1,040 tons,¹ and the figure for the *Canberra* is expected to be even higher. At this, they represent the largest welded aluminium alloy structures of any kind known to date.

For ship construction, specifically designed extruded sections including both bulb plates and tee bars are standardised in B.S. 2614. They combine the functions of stiffeners and permanent backing strips for the butt welding of deck plates, etc., and they have been used, together with special sections where required, in the construction of these superstructures. The alloy used for plating was NP5/6 (B.S. 1476), the aluminium magnesium alloy developed for such applications: it has outstanding resistance to marine corrosion and offers high weld efficiencies when joined by shielded-arc techniques.

Earlier in the year another major advance in the use of welded aluminium alloy took place in connection with the North Thames Gas Board scheme for storing liquid methane on Canvey Island. A converted tanker—*Methane Pioneer*—fitted with five 400-ton capacity aluminium alloy tanks, is used to bring the methane across the Atlantic to the Canvey Island installation, which comprises two cylindrical vessels constructed by different firms to the general specification of the North Thames Gas Board.

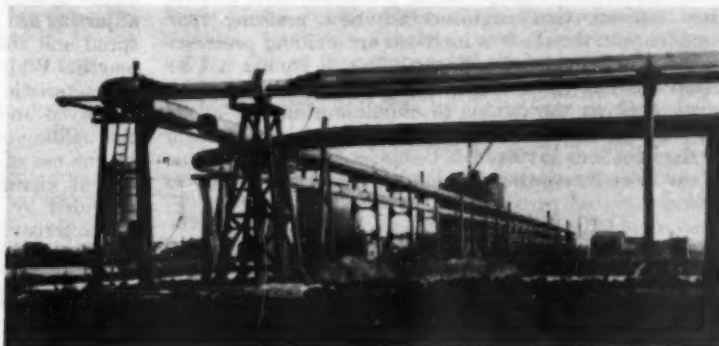
Each of the two contractors—The A.P.V. Co., Ltd., Crawley, and Whessoe, Ltd., Darlington—developed specialised design and construction techniques, and as a result there are certain differences between the tanks, particularly in the roof design. Basically, each vessel is 50 ft. high and 50 ft. in diameter, the wall thickness varying from $\frac{1}{2}$ in. at the bottom to $\frac{3}{4}$ in. at the top. Associated with these cylinders is some 2,000 ft. of seamless aluminium alloy pipe welded up from 20 ft. lengths.

A temperature of -160°C . is necessary to liquefy methane, in which state it occupies only 1/600th of its gaseous volume, thus making it more economical to transport. Much research work was undertaken to confirm that welded aluminium alloys were suitable for this type of application and four papers detailing some of this work have been published.² The material finally selected for construction of the storage tanks was again NP 5/6—an alloy on which considerable experience in welding and fabrication has been gained in recent years—and welding was carried out by the inert-gas metal-arc process only.

The tanks are not pressure vessels in the normally accepted sense of the term, but they are each required to hold 1,000 tons of liquid methane and the hydrostatic pressure at the bottom introduces appreciable stresses into the metal. At the same time, the low operating temperature causes considerable contraction problems, and leakages into the thermal insulation could not be tolerated. For these reasons all welds were radiographed, and tests carried out included vacuum box, dye penetrant and halide techniques. The whole of the welding was carried out on site, and in view of the rigorous inspection procedure it is not surprising that some re-welding was necessary. As the work proceeded the

Courtesy of The A.P.V. Co., Ltd.

A view of the aluminium pipes from the jetty to the methane storage tanks at Canvey Island.





Courtesy of The A.P.V. Co., Ltd.

Upward-looking view of the supporting scaffolding to the methane tank interior.

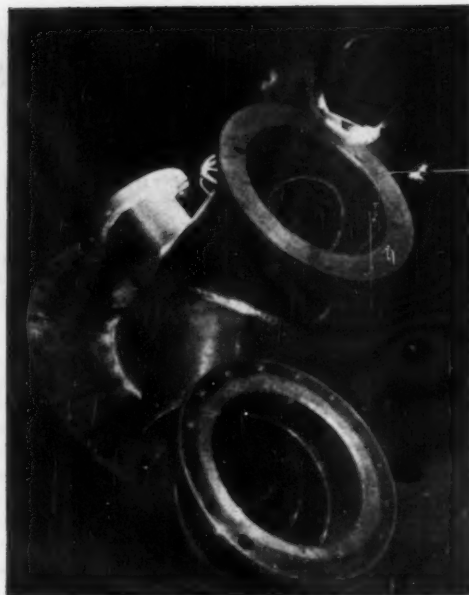
quality of the welding improved rapidly, so that very little re-welding was called for in the later stages.

During a symposium held in 1958, it was pointed out that welded aluminium pressure vessels had been produced in this country for over forty years—in fact, the first such unit made in this country, measuring 5 ft. 6 in. in diameter \times 12 ft. long \times $\frac{3}{16}$ in. thick, had been made as long ago as 1910.³ The main difference between these vessels and the Canvey Island tanks—apart from size—lies in the alloy and method of welding. The earlier vessels were made of commercially pure aluminium and welded by the oxy-hydrogen process, whereas the new tanks are made in an aluminium-magnesium alloy (NP 5/6), which in the fully annealed condition has a tensile strength of not less than 17 tons/sq. in.—three or four times that of pure aluminium. Even if alloys such as this had been available at the time the earlier vessels were made, it would have been impossible to attain reasonable weld efficiencies with the welding techniques then in use. Furthermore, a considerable amount of development and operator training must have been involved in producing such a high quality product in those days.

These three examples of the large scale application of welded aluminium alloys are of particular note in that they indicate that engineers are now realising that confidence in the modern inert-gas arc welding processes is completely justified. Nevertheless, it should not be imagined that those engaged in research and development work on the joining of aluminium and its alloys are relaxing their efforts; on the contrary, investigation of the problems involved is being intensified, and some of the more interesting developments will be referred to below.

Fusion Welding Processes

Although the tungsten-arc inert-gas process came into use during the war and the metal-arc inert-gas process was introduced into this country ten years ago, research



Courtesy of The A.P.V. Co., Ltd.

Welding the complicated manifold for the top of the methane tank.

and development work continues to increase our general knowledge and appreciation of the scope of the processes. As regards the tungsten-arc inert-gas process, which operates from an A.C. source in order to avoid melting of the electrode and yet to provide a fluxing action on aluminium, the use of the surge injection principle is now generally accepted and the other main development has been the production of smaller torches to provide improved access whilst still operating at reasonable currents. Where consumable-electrode inert-gas shielded processes can be employed, higher welding speeds are obtainable than with the tungsten-arc process. For materials of thickness in excess of about $\frac{1}{4}$ in. the latter process is unsuitable for production welding in any case.

Earlier sets available in this country operated the controlled-arc system using a power source with a steeply drooping volt-ampere characteristic. The rate of feed of the electrode wire was varied by the arc voltage to maintain a constant arc length in equilibrium with the predetermined burn-off rate setting. Although sets operating this system are still in service, modern equipments usually employ the principle known as the "self-adjusting arc." This employs a predetermined wire feed speed and the burn-off rate is dependent upon the arc length. Whilst arc control is obtainable with a drooping characteristic power source, the degree of control is improved and the selection of the machine setting for the welding of various material thicknesses is simplified by the use of a power source having a substantially flat output characteristic. The degree of self-adjustment provided by the use of a power source with a rising characteristic has been investigated⁴, and has been found to increase with the positive value of power source characteristic up to a value of $+0.04$ V./A., but with a steeper rise than this, arc instability occurred.

It may have been noted that several different descrip-

tions have been used above to denote the process employing a D.C. arc between the weldment and the filler wire shielded in an inert-gas atmosphere, and, in addition to the terms used above, the process is often identified by the trade names of the machines used—Argonaut, Sigma, Lynx, Fillerarc, etc. A common shortened term is obviously required and increasing use of the term Mig (metal-inert-gas) is apparent on both sides of the Atlantic. A similar term—Tig—has likewise found favour for the earlier process using A.C. and a separate filler wire.

The Mig process using a reel of (usually) 10 lb. of wire with a drive motor separated from the welding gun has some obvious disadvantages. The wire is pushed through a flexible tube in an atmosphere of shielding gas and the smallest wire diameter which passes at a uniform rate under these conditions without buckling, is $\frac{3}{16}$ in. diameter. Care is therefore necessary to avoid kinking the conduit, which in itself is somewhat more bulky, and hence troublesome in hand welding, than is the Tig welding cable.

The introduction in America in 1954 of the General Electric Fillerarc extended the range of wire sizes for Mig welding down to 0.030 in. This equipment incorporated the wire drive rolls within the gun, but the wire was pulled through the cable as before. Furthermore, the wire drive motor was situated alongside the reel, the drive being transmitted to the drive rolls by flexible cable. Since then guns incorporating a wire drive motor and 1 lb. reel have been developed in America, and two such units—the Rowen-Arc and the Sigmette equipments—are now available in this country.

The first fine wire equipments used in this country were specially converted guns of the previous standard size units, and the results of tests made with a gun of this type have been published.^{5,6} These tests were carried out on aluminium S1C and on alloys NS3, NS4, NS5, NS6 and HS30. The minimum thickness of material which can be welded by this process is dictated by the minimum arc currents which will provide a spray type transfer, and the tests were conducted to examine the range of arc currents and voltage which are practicable. With 0.020 in. diameter wire a minimum current of 75A. was found necessary for spray transfer, the figure being 50A. for 0.020 in. diameter wire. The work established that there was a linear relationship between minimum current for spray transfer and wire diameter⁷ and also that the critical range of current is to some extent affected by the arc voltage. With this modified equipment unbacked butt welds were made in material 0.036 in. thick, but for practical purposes it should be considered that with spray transfer conditions, the minimum thickness weldable with 0.030 in. wire are:—

Pure Aluminium	Aluminium Alloy	Butts	Laps and Fillets
S1C	NS3	0.080 in.	0.104 in.
—	NS4, NS5, NS6, HS30	0.064 in.	0.080 in.

There is no doubt that the welding speeds possible, and indeed necessary, with this process, are greater than with the tungsten-arc inert-gas process, and it is more suitable for fillet welding and positional work. Nevertheless, it must not be imagined that the earlier process has been rendered obsolete, there are plenty of instances where it is the more practicable process of the two.

The gas employed in this country is argon, with a minimum purity of 99.95%, as detailed in the relevant

British Standards, and since helium is not commercially available here, the claims from American sources of the advantages of argon-helium mixtures have received little attention in recent years. It has also been shown⁸ that chlorine additions are beneficial in Mig welding, but this introduces corrosion hazards to the welding equipment. Later work⁹ using similar equipment, but employing nitrogen additions with the object of reducing gas costs, has indicated that welds satisfactory for many less important applications can be obtained with this method in aluminium and aluminium alloys containing little or no magnesium.

Spot welds (full penetration welds) by argon-arc methods are of interest, since such methods would offer the advantages of portability of equipment, apart from any cost and reliability improvements. References have been made to the use of this process on aluminium alloys in America, and it is to be expected that progress is being made in development in this country.

Although of very little commercial interest, it must be noted that plant for welding metals by electron bombardment in vacuum is available and welds in aluminium are being made with this apparatus.

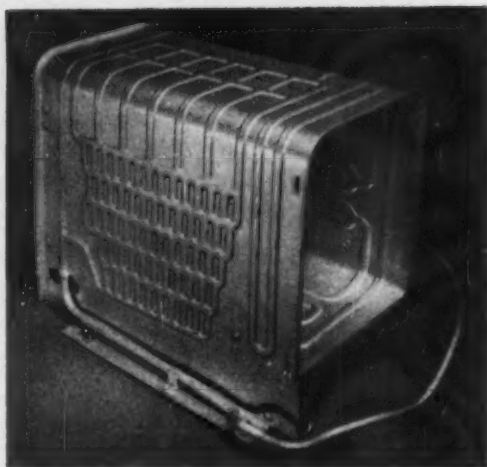
Other Welding Processes

In the field of pressure welding, the subject which has received most publicity in the last few years is that of ultrasonic welding. This process, which has been described elsewhere as a "sound" method of welding, was found to be a practical proposition as a result of tests made to study the effect of ultrasonic vibration during the production of resistance spot welds. During these tests it was noted that under certain conditions satisfactory spots were obtained without any current passing between the electrodes. Intensive development was begun in the United States in 1952 and machines of 4,000 W. capacity are now commercially available there¹⁰. The process is capable of producing lap joints only, the welds being either single or multiple spots or continuous seams. The two members to be welded are held together under a predetermined clamping force while one member is subjected to vibrations at a frequency above the audible limit. The vibrations are applied through the welding tips, known as sonotrodes, from transducers which develop mechanical energy through magnetostriction.

The welding machine must obviously include a power source, consisting of a variable-frequency generator and an electronic amplifier, in addition to the welding head comprising the transducer, sonotrodes and clamping system. A 2,000 W. unit takes up considerably more space than a contemporary three-phase resistance spot welding machine complete with electronic control cabinet, but at the other end of the scale a 50 W. ultrasonic welding array, which can make welds whilst being held in the hand, is driven by a generator occupying less space than the average domestic radio set.

The thickness of material which can be welded depends upon the material temper and the machine capacity available. The maximum thickness so far reported as satisfactorily welded by this method is 0.080 in. in high strength alloys and 0.120 in. in commercial quality aluminium. However, the scope and limitations of the process can best be understood by making comparisons with the well established electrical resistance and cold-pressure welding methods.

Aluminium may readily be joined by cold pressure



Inflated roll bonded panel formed into refrigerator evaporator.

welding, but this process requires very particular attention to the preparation of the faying surfaces within a short time of the welding operation and, furthermore, a compression force producing a very substantial deformation is necessary. In ultrasonic welding, however, the pressures required are far lower, the actual indentations produced being similar in appearance to those made in resistance welding—a total thickness reduction of 5–10% only. Even more marked is the difference in sensitivity to surface preparation; in ultrasonic welding of aluminium, surface preparation is necessary, but satisfactory welds have been made as long as twelve months after this preparation, though degreasing prior to welding is necessary.

Resistance welding is possible on materials thicker than with the present ultrasonic machines, but the newer process enables the production of satisfactory welds on very thin materials; foil as thin as 0.00025 in. can readily be welded. On the softer materials, within the thickness range encompassed by both processes, resistance welding is at present to be favoured, since the process limitations can be more precisely defined. For example, an ultrasonic welding machine must be carefully tuned to the resonant frequency of the welding array comprising the transducer, coupling bar, sonotrodes and weldment. Thus, for a given joint, optimum conditions may vary from machine to machine and must therefore be established by experiment. Satisfactory welds in the softer materials are comparable with resistance spot welds, but in high strength alloys, they may be expected to be superior to spot welds, since no heating is involved in the process.

American work has been directed towards the construction of larger machines to widen the range of materials, but no work has been published from this side of the Atlantic. However, 50 W. generators and welding heads are available in this country, and some work has been undertaken to establish the limitations of this equipment. At the lower end of the thickness range, this process may well find applications in the hermetic sealing of foil packages. The faying surfaces need not be free from marking since it has been shown

that satisfactory joints can be made between anodised or lacquered surfaces.

While straightforward cold pressure welding continues to find applications, one worker has given some information on experimental pressure welding using explosives.¹¹

Work continues on improvements in resistance welding machines to simplify the production of consistent spot welds in aluminium and its alloys, and three-phase welding machines with electronic controls capable of producing involved programmes of multiple heating and forging operations are now available.

While stud welding by orthodox stud welding gun methods continues to find applications, a method of production of studs by a resistance stud casting process has been reported.¹²

In the last year the installation in this country of a machine operating the Thermatool process has been announced.¹³ This machine is being used exclusively for the production of aluminium and aluminium alloy tubing. A continuous seam weld is produced by resistance heating at a frequency of 450,000 c./s. Since high frequency current tends to follow the path of least impedance, the heating effect is concentrated along the edges of the strip immediately before they are brought together in the tube-forming rolls. The process has been demonstrated as being capable of producing a satisfactory quality weld, and the tube made by this process will be free from eccentricity and possibly cheaper than solid drawn tube.

Before leaving the subject of welding, some reference must be made to the production of welded joints between aluminium and other metals. Examples of cold pressure welded joints between aluminium and copper are quite common¹⁴ and ultrasonic welding is also possible. Braze-welded joints are possible using a "buttering" of silver solder¹⁵ and on the subject of fusion welding of aluminium alloys to steel, work sponsored by A.D.A. will be published later this year.

Material Developments

It is now accepted that aluminium, aluminium-manganese (NS3) and aluminium-magnesium (NS4, NS5, etc.), can be fusion welded with high joint efficiencies. Other alloys which attain their high mechanical properties through heat treatment will obviously suffer from low weld efficiencies unless the weld metal is capable of responding to such heat treatments. Furthermore, the heat treatable alloys are more prone to weld cracking tendencies. However, the aluminium-magnesium-silicon alloys, H9, H10, H20, and H30, using aluminium-magnesium or aluminium-silicon alloy rods, can provide crack-free welds. Using inert-gas shielded arc welding methods, the heat affected zone is kept at a minimum and the rate of cooling is such that the weld bead is in the solution treated condition.

The higher strength aluminium-copper-magnesium alloys H14, H15, etc., have, until the last few years, been generally considered to be unweldable. Research into this problem^{16,17} resulted in the development of special welding rods to provide crack-free beads of compositions which would respond to heat treatment. The development of these rods does not, however, mean that these high strength alloys will be found in numerous welded applications in future, though interest in the possible

Courtesy of London Transport Executive.
The Routemaster bus with integral light alloy body.



use of such materials in certain specialised engineering structures has been roused.

In the same period, interest on the Continent was directed towards the development of aluminium-zinc-magnesium alloys containing up to 5.5% zinc and 2.5% magnesium. These alloys are claimed to offer good resistance to corrosion and weld efficiencies approaching 100%. These high weld strengths are developed by natural ageing for long periods—upwards of a month—but after this period welded test pieces are stated to have the following properties: 0.2% proof stress, 9–10.5 tons/sq. in.; tensile strength, 18–20 tons/sq. in.; and elongation, 15–20%. These materials are receiving attention in this country and are now in limited production.

The use of welded aluminium alloys in structures necessitates a greater understanding of the fatigue characteristics of welded joints and some work on this subject has been published.^{18,19} The British work was undertaken on HE30 and NP5/6 alloys which are finding significant application in engineering structures, and obtained values under axial stressing with a pulsating tension cycle, fatigue curves being plotted up to 2×10^6 cycles. It was concluded that the surface conditions of the weld very largely determined fatigue behaviour, and fatigue strengths of 3.5–7.5 tons/sq. in. (depending on weld geometry) were reported. Methods of improving fatigue strength by stress redistribution by mechanical or thermal treatments are being examined.

Standardisation

B.S. 2901—Pt. 2: "Wires for Gas-Shielded Metal-Arc Welding," which will shortly become available, includes details of rods for aluminium alloy welding by this process. Also in preparation is B.S. 3019—Part 3: "General Recommendations for Manual Inert-Gas Metal-Arc Welding Aluminium and Aluminium Alloys" and this will contain recommendations on all aspects of the process as applied to these materials. In the last few years The Aluminium Development Association has published a booklet entitled "General Recommendations for the Testing of Aluminium Fusion Welds and Welders," and it is expected that a British Standard incorporating some aspects of this will be published this year. The most universally used method of non-

destructive testing is, of course, that of radiographic examination, and although Xerography can be used to eliminate film costs this still remains an expensive test method. The use of ultrasonics in testing is possible with aluminium, but insufficient experience is available here to establish standards on which to base acceptance. This method is receiving considerable attention on the Continent, however, and it is therefore to be expected that the test cost component of high quality welding will decline in the next few years.

The 1959 Autumn Meeting of the Institute of Welding, held jointly with Société des Ingenieurs Soudeurs, had as its theme "Quality Control in Welding" and two papers dealing with the quality control of aluminium alloy resistance welding were delivered.^{20,21}

Brazing and Soldering

The use of aluminium-silicon brazing materials on aluminium and certain alloys has continued without modification, though "know-how" in respect of the limitations of the flux-dip brazing process is obviously increasing. This process has been employed on heat exchanger components for some time, and interest in the United States and Great Britain has extended towards the use of the process on the production of assemblies consisting of castings built up to provide the complex shapes and high degree of dimensional accuracy required by applications in the electronics industry. The soldering of aluminium presents difficulties in the initial wetting of the surface and also in the corrosion resistance of the joint produced. Nevertheless a number of solders are used for this purpose, the most satisfactory to date being zinc-base compositions melting at temperatures of the order of 350°–450° C. American sources have recently announced a new range of such solders and associated fluxes, but their efficiency has not so far been verified in this country.

Mechanical and Bonded Joints

The high welding speeds possible with Mig welding may well reduce the popularity of riveted construction, but nevertheless mechanical connections of this type have a widespread use, particularly with high strength alloys which suffer some loss of properties by exposure

to welding heat. Such mechanical fastenings are also required when making structural joints between steel and aluminium, as for example when connecting the aluminium alloy superstructure to the steel hull of the modern liner or naval craft, and when attaching the lightweight body of a modern road transport vehicle. When making such joints, due consideration must be given to the possibility of electrolytic corrosion, and as an example of modern practice the methods used on the *Oriana* are of particular interest. The vertical connections here comprise lap joints using steel rivets driven into countersinking in the steel member. The interface between the members is protected by the introduction of lacquered aluminium foil and sealed by fillets of epoxy resins. At the root of the fillets, where shear concentrations would occur in the resin, aluminium wire is sited to reduce the possibility of crack formation in the fillets.

Phenol-formaldehyde/Formvar resin compositions have been used for jointing aluminium alloys in aircraft since the earlier days of the last war, and more recently epoxy resins have been similarly employed. Apart from certain formulations necessitating high temperature curing treatments, these can produce stronger lap joints than are possible with rivets, and the use of adhesives has replaced rivets in other industries as knowledge of their properties has increased.

Some Notable Applications

Reference has earlier been made to the aluminium alloy welded superstructures of the liners *Oriana* and *Canberra*, but there are numerous other examples of the use of these materials worthy of mention. These represent very substantial tonnages, although the unit weight is less impressive than in the liners. For example, the patrol boat H.M.S. *Brave Borderer* was passed through its trials last year. This gas turbine powered craft may operate as gunboat, torpedo gunboat or minelayer, is capable of speeds in excess of 50 knots, and has an all-welded hull frame in NS5 and NE6 alloys.

Inert-gas arc welding methods were used to produce units of box frames for staging towers for radar or microwave communication systems. These can be quickly erected and dismantled and economically transported. It is reported that a 204 ft. tower can be erected by eight men in four hours and that when dismantled it can be carried on one 2-ton vehicle.

Welded aluminium alloy bridges have been reported from overseas, and flash welded aluminium alloy window frames are appearing on numerous building projects in this country. The all-welded heat-treated aluminium alloy milk churn is now well established, and a bulk farm milk tank of welded aluminium alloy has recently been inspected after 18 months service and found to be in perfect condition. Pressure welded applications range from container seals to roll bonded refrigerator evaporators, whilst some types of heat exchanger components also use this method of joining.

In the railway modernisation programme large quantities of diesel sets are now making their appearance in which the use of aluminium alloys is quite evident. The design of the new diesel locomotives also takes advantage of the saving in weight possible, both welding and riveting being employed in these railway applications. Similarly, the aluminium train sets are appearing on London's Underground and the Routemaster light alloy bus is now in service on several routes in London.

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Importer Rectifier Order for Norway

In the face of severe competition from the Continent, the Heavy Plant Division of Associated Electrical Industries has secured a contract from Norway for a 108,000 kW. rectifier installation required in connection with aluminium smelting. This rectifier equipment is believed to be the largest of its kind yet ordered. The contract has been placed by Ardal og Sunndal Verk, the equipment being for important extensions to their existing plant at Ardal—situated at the head of the Sognefjord on the west coast of Norway. A/S Ardal og Sunndal Verk are already the largest producers of aluminium in Norway and the new extensions represent an increase in production capacity of 32,000 tons per annum.

The order covers semiconductor rectifier equipment rated at 135,000 A., 800 V., D.C., and the plant is to be commissioned and in commercial operation early in 1962. We are informed that A.E.I. germanium rectifiers were selected on the technical merits of the equipment put forward compared with other similar types of rectifiers, and on the successful operating experience already obtained in service with A.E.I. equipment.

The transformers required to operate with the rectifier equipment will be manufactured in Norway by A/S Rich Pfeiffer, with whom A.E.I. have collaborated in the overall design of the installation. Apart from minor items of auxiliary equipment, the whole of the rectifier equipment will be manufactured in factories of the Heavy Plant and Motor and Control Gear Divisions of Associated Electrical Industries, Ltd. Consultative and technical services in the design and layout of the electrical plant are to be provided by A.E.I.

Enamelling Aluminium

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The past decade has seen vitreous (porcelain) enamelling of aluminium established commercially. In this account, alloys suitable for enamelling are indicated, with particular reference to their treatment prior to processing. Details are also given of techniques for milling the frit, spraying on the slip, and firing the enamel. Tests for checking the quality of the product are enumerated and some current applications briefly mentioned.

THE increased usage of aluminium in many fields has been accompanied by rapid developments in decorative and protective coatings. In the early days of aluminium manufacture, conventional finishes such as paint and lacquers were quickly adapted to this "new" metal, chemical finishes were developed, and later modified electroplating practice evolved, whilst anodising firmly established itself as a protective and decorative finish in the 1930's. For some years vitreous enamel ("porcelain" enamel in American terminology) was the only finish not obtainable on aluminium. The early post-war years saw new efforts being made to solve this problem, and a decade ago early frits developed by Du Pont were being used commercially in a small way in the United States. In Great Britain two companies were engaged on development work and one of them was operating a small pilot plant. These early activities have been reported elsewhere.^{1,2}

In Great Britain progress in this field has been slow, and it is only in the last two years that vitreous enamelling of aluminium has become established as a commercial process. On the other hand, development in the United States has been more rapid and there are several dozen companies operating in this field, principally enamelling aluminium for building and architectural applications, road signs and advertising panels, domestic appliances and similar products.

It seems appropriate to consider the ways in which vitreous enamelling on aluminium differs from the method for steel, and the particular features of aluminium enamelling technique which require attention. A basic problem has been the low melting point of aluminium (659° C.), which is lower than the firing temperature of many steel enamels: the recommended firing temperature for aluminium is 520–570° C. The starting point of vitreous enamel is the basic material—a glass-like coarse powder—known as frit. These frits are ground with water, other oxides required to give the desired colour, and an addition agent, to produce a smooth finely-ground slurry (called "slip") which is sprayed onto the surface being enamelled. This coating is then fired to produce complete fusion of the enamel constituents.

The problem of the frit manufacturer has been to develop a frit for aluminium having a melting point low enough to enable the enamel to be fired in the temperature range given above, having a coefficient of expansion near that of the metal, and as many as possible of the normal application characteristics of steel enamel. As might be expected, some compromises have had to be made, but an acceptable product has now been evolved. The past ten years have shown that these enamels have properties that should ensure their acceptance as useful



Fig. 1.—Panel of enamelled commercial purity sheet showing "strain-lining" after double firing.

finishes for a number of applications. Once a satisfactory frit has been developed, successful enamelling depends upon the use of suitable grades of aluminium, and close control over each production stage—pretreatment, spraying, milling and firing.

Materials for Enamelling

Little is known of the nature of the bond between the enamel and the metal. Steel usually has a coating of mill scale or rust and, even with present cleaning methods, the use of a specially formulated ground coat is often necessary to produce a satisfactory adhesion and colour. With aluminium, satisfactory properties can usually be obtained by application of a single coat of adequate thickness direct on to clean metal; pastel shades may require two coats to give the desired opacity.

Experience has shown that not all aluminium alloys enamel satisfactorily; those containing more than small amounts of copper and magnesium cannot be enamelled since the coating flakes off, either during firing or on cooling. This restricts the range of alloys which can be treated, but other factors have also to be taken into account. A defect known as "strain-lining" can be met



Fig. 2.—Furnace used for the firing of enamelled architectural panels at the works of Ernest Stevens, Ltd.

Courtesy of the Vitreous Enamel Development Council

with, particularly where two coats are applied, which takes the form of partially healed cracks in the enamel (Fig. 1). This is especially prone to occur in some materials, particularly aluminium of commercial purity or higher purity (materials 1C, 1B, 1A and 1 (B.S. 1470-1477)—Noral 2S, 1S, 99.8% and 99.99%, respectively, in the Northern Aluminium range).

On the other hand, the 1½% manganese alloy NS3 (3S) is universally found to be satisfactory for enamelling even when given only a simple cleaning treatment, such as a light alkaline etch and acid de-smut. Normally produced only in sheet form, this alloy can be obtained for special enamelling requirements in sections and tubes, but in these forms there can be difficulties with some shapes in maintaining a good surface finish. Limited experience with extrusions in aluminium-5% silicon alloy N21 (33S) shows this to be a satisfactory alloy for enamelling in extruded form.

The main disadvantage of NS3 is the low strength resulting from annealing when the enamel is fired. This has encouraged work to be carried out on the enamelling characteristics of the stronger alloys, and the most satisfactory alloy to date is the heat treatable alloy HE30-WP (B51S-WP) containing nominally 1% silicon, 0.6% magnesium, 0.4% manganese. However, this alloy requires a more elaborate pretreatment, including chromating and pre-firing. Another suitable alloy is HE20-WP (65S) which has been used as an enamelling alloy for several years in North America, but it is not so popular in this country and, if anything, its enamelling characteristics are slightly inferior. Certainly a similar, somewhat lengthy, pretreatment is equally necessary. There also appears to be general agreement on both sides of the Atlantic that H9 (50S) is the least satisfactory for enamelling of the aluminium-magnesium-silicon alloys and its use is not recommended. The only failures of enamelling seen by one of the authors, on a recent visit to the United States, was on extrusions in this alloy. After firing, these alloys have properties approximating those of the W (solution treated) condition: these can be improved by a low temperature heat treatment, but full WP (solution treated and precipitation hardened) properties cannot be guaranteed.

However, not only the alloy itself but also its semi-fabricated forms are of significance for enamelling. In sheet form the alloys NS3 (3S) and HE30-WP (B51S-WP) give few problems if the correct procedure

is followed. Some North American fabricators have preferred to offer architectural panels made from roll-formed sheet to those made up from interlocking extrusions. On the other hand, several other companies use extruded sections quite successfully, but attention is paid to the design of the extruded section, since corners and sharp changes of section are potential sources of trouble both in enamelling and from spalling during subsequent service. Certainly sheet predominates in American enamelling applications.

Castings present a particular problem in which the alloy plays only a small part. It is possible to enamel successfully aluminium-silicon alloys, such as LM6-M LM18-M, but the prime requirement is to have a sound casting with a good surface. Here both the design of the component and the skill of the foundryman play their part. So far in this country there has been no more than development work carried out on castings, but one American company is known to be in production with a range of gravity (permanent mould) die cast hollow-ware, enamelled on the outside only.

Pretreatment

It is an axiom that any cleaning cycle for metal must take into account the contamination it is expected to remove. The enameller may have to take metal as supplied and be expected to process it satisfactorily with a minimum knowledge of its previous history. Pretreatment of aluminium for enamelling is expected to provide a chemically clean surface, and one to which enamel will bond satisfactorily. As indicated above, different alloys behave differently in enamelling so the pretreatment given must take this into account.

Materials can be broadly grouped into those for which a simple degreasing-etch treatment is normally adequate, and those for which chromating and pre-firing are essential. The recommended pretreatments are summarised in Table I.

The use of chromic-sulphuric acid mixtures for cleaning aluminium is well established (see D.T.D. 915a), while the use of a 3.5% chromic acid-17.5% sulphuric acid (by wt.) mixture which may also contain up to 2% hydrofluoric acid was disclosed in an American patent.³ The advantage of these chromic-acid-based solutions is that they will readily remove the surface oxide from heat treated alloys; this oxide can be troublesome on sheet

products. Sometimes it may be an advantage to use the chromic pickle prior to alkaline etching to remove surface oxide, confining the treatment after etching to $\frac{1}{2}$ -1 min. Typical compositions and operating conditions of these pickling baths are:—

- (1) Sodium dichromate 7.5% (wt.)
Sulphuric acid 15% (vol.)
Temperature 65-80° C.
Time 2-5 min.
- (2) Chromic anhydride 4% (wt.)
Phosphoric acid (s.g. 1.70) 7% (vol.)
Temperature 75-95° C.
Time 2-6 min.

The chromate pretreatment prior to pre-firing may be one of several proprietary processes, but that recommended by Du Pont⁴ is most widely used:—

Chromic sulphate	0.024 lb./gal.
Potassium dichromate . .	1.75 lb./gal.
Sodium hydroxide	0.95 lb./gal.
Water	to 1 gal.
Temperature	50 ± 2° C.
Time	2-5 min.

Make-up of the bath is important in that the dichromate and the caustic soda should be placed at opposite ends of the tanks and dissolved by adding most of the water cold. The chromic sulphate is dissolved in the remaining water and then added to the rest. The slight precipitate which forms should be left and not filtered off. The composition should be checked on make-up and also daily during use, and controlled at 17-21% (wt.) potassium dichromate and 3.5-4.1% (wt.) free sodium hydroxide.

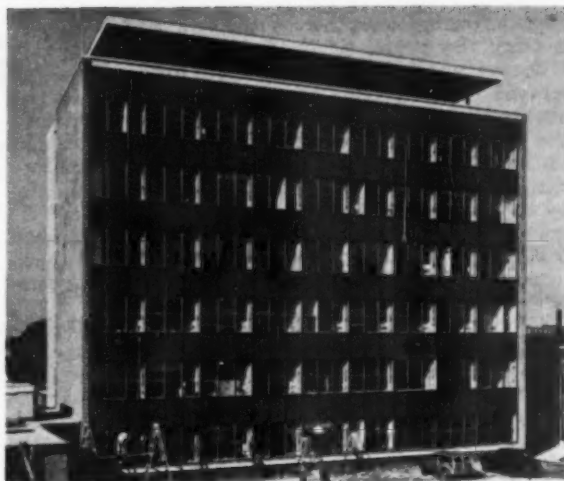
Milling

The frit supplied is normally a coarse powder requiring ball milling to bring it to the desired fineness—which is finer than is normal practice for steel enamels. The various factors relevant to fineness of grind have to be examined for any given mill but, as a general rule, about half of the ball charge should be balls of $\frac{1}{4}$ - $\frac{1}{2}$ in. diameter, and the balance balls of $\frac{1}{2}$ -1 in. diameter. This balance should be maintained by periodic removal of undersized balls. The ball charge should be about half of the mill volume and the frit charge about a quarter of the volume.

The final finish obtained is very dependent upon the original sprayed finish, which in turn is governed by the viscosity of the slip. Since the slips used on aluminium are strongly alkaline, it has become common practice to make a "mill addition" that has the dual function of providing a slip of the correct viscosity and preventing attack of the metal by the slip before firing is complete.

TABLE I.—PRETREATMENT RECOMMENDATIONS FOR VARIOUS ALLOYS

NS3 (38) [also S1C (28) and N21 (33S)]	HE30-WP (B51S) [also HE20-WP (63S)]
Alkaline etch (e.g. 2-5 min. in 10% NaOH at 60° C.)	Preliminary clean (e.g. 2-5 min. in 10% NaOH at 60° C. or 2-5 min. in 6-15% (w/v) H ₂ SO ₄ at 75- 85° C.)
Rinse	Rinse
De-smut in 25% (vol.) HNO ₃	Pickle in CrO ₃ -H ₂ SO ₄ or CrO ₃ -H ₃ PO ₄ at 65-80° C. for 2-5 min.
Rinse	Rinse
	Chromate Pickle
	Pre-fire 5-10 min. at 560° C.



Courtesy of F. Pooler, F.R.I.B.A., County Architect, Bucks, C.C. and Aluminium Building Components, Ltd.

Fig. 3.—Infill panels in NS3(3S) sheet vitreous enamelled with a non-leaded frit.

Addition agents are offered by the frit manufacturers; the following composition has also been found satisfactory:—

	parts by weight
Potassium hydroxide	34
Boric acid	37
Sodium silicate	15
Water	15

The actual mill loading is governed by the final colour required, and the amounts of frit and oxide are varied accordingly. The addition agent controls the viscosity of the slip, but is also formulated to stop metal attack when the slip is sprayed on and fired. A typical mill loading is given below, although in the case of pastels the term colour must be taken to mean titanium white plus colouring oxide:—

	parts by weight
Frit	500
Addition agent	38
Colour	25
Water	250

Milling should be continued until a 50 ml. sample of slip poured through a 325 mesh sieve leaves not more than 0.1 g. as residue on the sieve. This requires considerable care, in that the slip should be well washed through the sieve with water, but not at high pressure. The residue should be carefully dried and weighed on a laboratory balance. Inadequate milling will result in a coarse "bitty" finish.

Spraying

This operation is more of an art than a technology. Handling a spray gun to apply slip calls for a certain degree of skill and experience. Uniformity of coating thickness over the surface can be important in determining both colour and weather resistance. Also, since the coating does not have the secondary flow characteristics of a paint coating, the sprayed finish largely decides the final finish.

When handling large quantities of similarly shaped articles such as building panels, an automatic spraying system can be used which will give surprisingly consistent results on flat pieces. Where the panel contains

ridges or corrugations, there is usually a need for supplementing the automatic line with hand touching up. When commencing with a new colour the weight of slip sprayed on a standard panel, and the final thickness obtained on firing should be checked. Having obtained the correct coating weight to give the desired enamel thickness, this should be checked twice daily to ensure that conditions are being maintained. This should also be supplemented with a similar check on the specific gravity of the slip. A coating thickness of around 0.004 in. is preferred for architectural work and thicknesses of 0.0025-0.0030 in. for less severe applications.

Firing

Experiences have already demonstrated that apart from poor pretreatment, inadequate firing is the most common cause of failure in service. It is necessary to ensure that a given furnace does, in fact, raise the work being processed to the temperature indicated on the controls and that the time is long enough to ensure complete fusion of the enamel. If visual examination of panels after firing for various times and temperatures is supplemented by PEI acid resistance tests,⁵ the effects of these variables become evident: the results of such acid resistance tests have been the subject of an earlier account.⁶ Firing times of 7-15 minutes are frequently used in practice.

The two non-leaded frits most widely used in this country at present, Ferro Enamels, Ltd., A18 and Blythe Colour Works, Ltd., AM80, fire best at around $560 \pm 10^\circ \text{C}$. The leaded frits, such as those offered by Du Pont, have a somewhat wider tolerance on firing temperature, $520-560^\circ \text{C}$. being possible, but at the lower temperatures some increase of firing time is necessary to compensate. Production furnaces are normally electrically heated and fitted with a continuous conveyor. The furnace speed should be adjusted to suit the amount of metal being handled, since the heat required to bring the metal up to temperature is the major part of the heat required. Thus, a furnace may be designed to handle metal having a weight equivalent to 12 lb. emerging every minute. Extruded sections would therefore demand a slow speed of perhaps 2 ft./min., whilst light gauge sheet would be processed at, say, 4 ft./min. A typical furnace installation is shown in Fig. 2.

Testing the Product

Having produced an enamelled product, both the enameller and the user have an interest in ensuring that the product is satisfactory. The first test which will always be applied is the visual one. To the expert eye a good deal of information can be obtained from visual appearance, since the presence (or absence) of metal attack can be readily detected; the uniformity of appearance will indicate whether spraying has been properly carried out; and the gloss will indicate the adequacy of firing.

If these features are satisfactory, the next test will be to bend a test sample around a $\frac{3}{4}$ in. diameter mandrel. If the enamel does not flake off then this is an indication that there is no gross lack of adhesion. If the same bent specimen is subjected to the PEI spall test⁷ by placing in a 5% ammonium chloride solution and examining at the end of 96 hours, the absence of spalling, particularly around the bent portion, will indicate satisfactory pretreatment. Extrusions and castings cannot be bent easily, but the sensitivity of the test on flat specimens

can be improved if a grid of lines forming squares of 1cm. side is scratched through to the metal. Supplementary information on the adequacy of firing can be obtained from the PEI acid resistance tests, ratings of A and AA normally being obtainable. Other tests, such as those for alkali resistance, colour retention and abrasion resistance, have been compiled by the American Porcelain Enamel Institute, but these are only invoked in special cases.

Applications

It is evident that the product is still in its early days and that information is still being accumulated on its properties. Since vitreous enamelling provides a new texture and a range of fast colours for the decoration of aluminium, there is no doubt that it will establish a market for itself as a finish in its own right. It has



Courtesy of Franco British Signs Ltd.

Fig. 4.—Prototype road traffic sign using NS3 sheet.

already found application in this country for infill panelling on the exterior of buildings (Fig. 3) and experiences of up to ten years in the United States suggest that its durability will be adequate. Exposure tests over several years in this country, which are still continuing, seem to confirm American experience. Indications are, however, that panelling formed from sheet rather than extrusions will be the major market here.

Another field of application is highway signs (Fig. 4) for which enamelled aluminium is particularly attractive since it does not chip in the way which its steel counterpart does. Further, even if any metal is exposed, there are not the unsightly rust stains which are inevitable with steel. For these reasons, one British company has recently produced hundreds of black and white enamelled aluminium street lighting reflectors for a new road lighting scheme. Bathroom tiles in a range of colours are also offered commercially. (continued on page 81)

Aluminium and its Alloys in 1959

Some Aspects of Research and Technical Progress Reported

By E. Elliott, A.Met., F.I.M.

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Attention is drawn to work published in this country and the U.S.A., reporting research and technical progress in the various aspects of the metallurgy of aluminium and its alloys, including extraction, founding, fabrication, constitution, properties and standardisation.

Reference is also made to interesting applications of these materials.

THE assembly of industry into fewer, larger units is a process which has continued throughout the present century, and the past year has been noteworthy for changes in the ownership of parts of the aluminium industry in this country. One effect of this has been to draw public attention to the status of aluminium and to the fact that it has become, despite its short history, the second most important metal in volume of use. Articles dealing with amalgamations have appeared even in popular journals, as, for example, an account by Lincoln¹ in a well-known American weekly. Despite these commercial upheavals, technical and scientific advance has continued steadily, as recorded in the usual articles and papers, varying from the exciting to the pedestrian, but nearly all of value in adding to the sum of knowledge about aluminium and its alloys.

Production

Although improvement in industrial activity led to rising demand for aluminium ingot as the year wore on, the period under review was not notable for announcements of increased production capacity. Nevertheless, progress has continued, and an important additional extraction plant in Norway² has an annual output capacity of over 36,000 tons, and further expansion is planned. Arrangements have been completed to establish an integrated aluminium-producing industry in India³; the plant, in the centre of the sub-continent, will begin to operate in 1962, producing 20,000 tons of metal a year from local bauxite. Even further east, it is claimed that Japan is a museum of minerals, and Ogawa⁴ has described how these are used as sources of non-ferrous metals. Aluminium production is nearly 70,000 tons yearly and the purity of the primary metal is high, while one company is producing refined aluminium as pure as 99.998%.

Melting and Casting

The natural habitat of the metallurgist is said to be the foundry, and melting is the first step in nearly all metal manufacturing operations. Bunbury and Rogers⁵ have given an account of modern methods of melting for the non-ferrous founder, concentrating on the attainment of quality, particularly as regards degassing, impurity control, and, with aluminium-silicon alloys, modification. They note that aluminium alloys are not so susceptible to losses on melting as are other non-ferrous metals, probably as a result of the presence of a

protective film of alumina on the surface of the melt. Much is owed by aluminium to its oxide. Some problems in degassing technique have been discussed by Kessler,⁶ particularly as regards materials for tubes for conveying chlorine into the melt. Enamelled iron tubes worked well, but the enamels easily chipped, and in the foundry the tubes had only a short life. The addition of solid degassing agents and grain refiners to aluminium alloys involves plunging to ensure that the effect reaches the bottom of the melt, but this has now been obviated by the development of a self-sinking⁷ addition.

As the Prince of Morocco said, farewell, heat, and welcome, frost; after melting must come freezing. Sergeant⁸ has employed a "marker technique" to indicate the solid-liquid interface during solidification, by adding aluminium-copper hardener to small partly frozen ingots. He concludes that pure aluminium freezes with a smooth solidification front, but aluminium-2% silicon alloy by dendrite formation. Using an aluminium-12% silicon alloy, amongst other materials, Berry, Kondic and Martin⁹ have determined solidification times of simple shaped castings in sand moulds, for a large range of dimensions and various mould conditions. They have been able to develop a method of predicting solidification times and have compared the theoretical chilling power of mould materials with practical results, with satisfactory agreement.

Equilibrium diagrams may tend to be neglected by the practical foundryman, but Wallace¹⁰ shows that he does this at his peril, and Stonebrook¹¹ drives the point home with special reference to light metals. The diagrams are studied from the point of view of cooling and also as a basis for the design of heat treatments.

Tests of alloy properties important in the foundry, such as fluidity and cracking, continue to accumulate, but Flemings¹² and his colleagues disarm criticism in the first four words of their paper; they describe their achievement as "still another fluidity test." They use it to study the effects on fluidity of various mould coatings; the most efficient was hexachlorethane, and a number of theories to explain the mechanism of improvement are discussed. Gamber's¹³ cracking test consists in casting thin elongated channel sections with short upright ends, and results with aluminium alloys are stated to be in good agreement with foundry experience.

Although there are many methods of producing castings in aluminium alloys, only three are of major importance, namely sand casting, gravity die casting

and pressure die casting. The relative merits of these, and the tendency for production to shift from sand through gravity to pressure, have been considered by Fenn¹⁴; his paper is particularly valuable since he has himself been active in the casting of aluminium alloys in permanent moulds throughout practically the whole of its history in this country. His advice that great care must be exercised in choice of method must be closely heeded by the casting designer and user, and also by the founder.

Langenheim¹⁵ has discussed the approach of the space age in the foundry; he is not considering the more spacious days for which we all hope, but the use of castings in space vehicles. He sets the aluminium founder the task of producing castings with tensile strengths consistently around 60,000 lb./sq. in.; no mean requirement. Hanson¹⁶ has also taken a look at the missile and aircraft field, and he sees a bright future for the foundry willing to produce castings of high quality, not only as regards metallurgical aspects, but with close dimensional tolerances. He describes the foundry techniques that he himself uses to fulfil these requirements. The small foundry is at a disadvantage in the production of high quality castings because of its lack of metallurgical testing facilities; Martin¹⁷ points out methods by which the disability may be overcome, including a mild application of statistics.

Water can be the great enemy of the foundryman, particularly as a source of hydrogen in aluminium alloys. Black¹⁸ has described the making of moulds using oil-bound sands without water, and he claims a number of other advantages including good casting surface. No reference is made to the use of such sands with aluminium alloys containing large additions of magnesium, but it is stated that for magnesium-base alloys special precautions are necessary. Using vibration at varying frequencies during solidification, Garlick and Wallace¹⁹ have produced grain refinement in a number of metals and alloys, including pure aluminium, aluminium-4½% copper and aluminium-12% silicon alloys. It is concluded that the effect is most marked with materials of high solidification shrinkage, so that it is efficient with aluminium and its alloys.

While recognising that in gravity die casting solidification times and permissible operating rates are influenced principally by casting thickness, Goodwin and Hunsicker²⁰ have shown by experiment that significant changes in these operating characteristics may be made by varying mould thickness. For any specified rate of solidification, more rapid production is possible with thick moulds, but increase in thickness is limited by handling difficulties due to weight. A very specialised foundry operation is the production of rotor bodies for electric motors; Atkinson²¹ has explained how this is done, using pure aluminium in moulds spun centrifugally to ensure soundness in the bars and end rings. This process has been mechanised to a remarkable extent. Vacuum pressure die casting seems to be rather a contradiction in terms, somewhat like good tax-collectors or bad beer, but nevertheless, the evacuation of the die before the entry of the metal holds out important advantages; more attention must undoubtedly be paid to this development. A recent description²² of the process includes also automatic ladling, in which atmospheric pressure is used to force molten metal into the evacuated shot sleeve, ready for injection into the evacuated die. It is claimed that the improved casting quality leads

also to lower costs per piece, and that the method may be used with advantage for both aluminium and zinc. In the United States, competition between pressure die foundries is strong. Found and Lapin²³ have concluded that, as a result, metal cost is the dominant factor in determining profits. They offer an interesting guide to the factors contributing to metal cost, and advice on how to keep it as low as possible, pointing out that this does not involve simply beating down smelter prices.

Christian missionaries in China in the past were assiduous in their efforts to end the pernicious practice of binding the feet of little girls; perhaps now we can expect some reciprocity action by the Chinese, regarding the ill effects of wearing "stiletto" heels, upon which so many Western women of all ages now hobble, with the assistance of the aluminium foundry industry. Two methods have been described of manufacturing these abominations, by gravity²⁴ and by pressure²⁵ die casting. The results are similar and the eventual pressures exerted on commutatory male toes equally high.

The aluminium-copper-silicon alloys are a very important class in the foundry, and it is correspondingly useful to have Ridley's²⁶ summary of published information about them. A special report on the production of aluminium alloy castings with high properties²⁷ is divided into three parts, devoted to the techniques involved, and examples of their applications. The alloys chiefly considered are high purity versions of the aluminium-silicon-magnesium and aluminium-silicon-copper-magnesium types, and into the former class falls also a proprietary alloy²⁸ used for high strength aircraft castings.

Kessler²⁹ has described the grain refinement of aluminium-magnesium casting alloys by the introduction of carbon tetrachloride by a carrier gas. He notes a number of improvements, but of special interest is the claim that the tensile strengths of the alloys remain constant in the range 20–300°C., while, as is well-known, aluminium-magnesium casting alloys normally weaken rapidly at elevated temperatures. The advent of the aluminium alloy cylinder block has concentrated interest on hypereutectic aluminium-silicon alloys in view of the possibility of using them as cylinder bores without ferrous liners or other measures against abrasive wear. The properties of these alloys have been discussed by Kissling and Tichy,³⁰ who also consider the possibility of using them as liners for blocks cast in conventional alloys.

A well-known aluminium foundry in this country has celebrated its silver jubilee,³¹ and its gravity and pressure die casting shops have been described. In the United States, there is a move by the large motor manufacturers into the field of aluminium casting; Chrysler³² and Ford³³ have opened foundries, the former for pressure die casting, and the latter for both forms of die casting. Ford use hot metal delivered from a reduction plant a quarter of a mile away. Any alloy is used, so long as it is SAE 308—an aluminium-silicon-copper alloy similar to LM24-M.

Little has appeared during the year regarding billet production, but an account has been given of the automatic displacement die casting of slugs³⁴ for impact extrusion.

Working

North Wales has a place in the history of the aluminium industry as the home of a former extraction

works, no longer in production. The company concerned, namely Aluminium Corporation, Ltd., is still active in semi-fabrication, and celebrated in 1959 its Golden Jubilee³⁵; coincidentally it installed a modern 2-high reversing mill for the breaking down of rolling slabs. This makes possible a 50% increase in output by the company of sheet and strip, at a particularly suitable time in its development. The visit of the Institute of Metals to Sweden for its autumn meeting resulted in the publication of a number of interesting descriptions of Swedish works engaged in various phases of working aluminium and its alloys. One of these companies³⁶ has been in existence since 1607, and is now concerned with copper, aluminium, zinc, and even plastics. Another is principally a foundry and extrusion works³⁷ but also produces some finished goods. A third is a world-famous manufacturer³⁸ of packaging items in aluminium, including collapsible tubes, bottle capsules, and foil containers.

Despite the reduction in military aircraft production, which is the main outlet for aluminium alloy forgings, interest in the process continues; indeed, the forge attracts the metallurgist to a degree second only to the foundry. Ploughshares and pruning hooks should never be scarce, and other non-warlike uses of forgings are constantly being sought. Jackson³⁹ has looked at the forging industry generally, including that devoted to aluminium, and drawn attention to the large presses in use in the United States, including one of 35,000 and one of 50,000 ton capacity. Forging capacity has changed considerably since Falstaff asked to be filled with a three-man beetle, and after this, a 4,000 ton press may seem small, but it is, of course, much more versatile than the giants, which are tied to a very limited market. A direct-acting 4,000 ton hydraulic press has recently been installed in Birmingham,⁴⁰ after a chequered career involving manufacture in Germany and confiscation by Holland as war reparations.

Research into the mechanism of the extrusion process continues at the National Engineering Laboratory, and the results obtained with aluminium⁴¹ have been summarised. The materials used were 99.5% pure aluminium and the high strength aluminium-zinc-magnesium-copper alloy D.T.D. 363, which could certainly be claimed to represent the extremes of the whole range of aluminium-base materials usually extruded. The effects of a number of variables have been studied, including ram speed, extrusion ratio, billet temperature and extrusion pressure. Wilcox and Whitton⁴² have used room temperature and super-purity aluminium for a fundamental study of slow-speed, lubricated extrusion, with dies of semi-cone angle varying from 30° to 90° and extrusion ratios varying from 2:1 to 100:1, with lanolin as a lubricant. A general equation is derived relating the inverted extrusion pressure to the semi-die angle and extrusion ratio, and the pressure for direct extrusion may be obtained if the coefficient of friction between the billet and container wall is known.

It has long been the aim of metallurgists, from Bessemer onwards, to be able to go straight from melting furnace to semi-fabricated product without the intermediate step of billet casting and re-heating, and varying measures of success have been attained by equipment devoted to such processes. Russell and Nichols⁴³ have described in detail the Properzi technique for the production of hot-rolled rod, subsequently drawn into wire for conductor and cable manufacture. The most recent Properzi installations cast a continuous billet of

1½ sq. in. cross-section, which is fed direct to a train of rolls which has 13 stands in tandem, and takes the material down to ½ in. round rod ready for drawing. The Hazelett and rotary strip-casting machines have been discussed by Hamer,⁴⁴ who shows that for pure aluminium both are successful and likely to find extended application, while more experience is required to forecast their suitability for production of strip in aluminium alloys under works conditions.

As a further step in its programme of installation of new plant, the Northern Aluminium Co.⁴⁵ has obtained a batch-type furnace for the annealing of hot-rolled plate, before cold rolling to lighter gauges. This furnace will take material 6 ft. 6 in. wide, 65 ft. long, and up to 16 tons in weight, and the necessary handling equipment has also been installed. Rapid heating by radiation is used in a continuous flash annealing furnace⁴⁶ for circles of alloy NS3, to ensure fine grain for deep drawing. This method of heating also avoids oil staining which can arise in conventional annealing. Sargent⁴⁷ has proposed a test to evaluate rolling oils as regards their tendency to staining, involving the oiling and annealing of "standard stainplates," which are produced with specially uniform surface, flatness, and brightness, and subsequent comparison with standardised stains. If aluminium collapsible tubes are to be true to their description, they must be completely softened⁴⁸ after manufacture, and a conveyor type furnace for this purpose has been described, which uses high temperature radiant surfaces and high velocity air circulation. An account has been given of furnaces and equipment for the annealing and solution treatment of aluminium and aluminium alloy wire.⁴⁹

A continuing problem with heat treated aluminium alloys, particularly in large pieces, is the internal stress caused by quenching after solution treatment. It can cause distortion on machining, and accentuated danger of stress-corrosion in alloys susceptible to this form of failure. One way of overcoming such stress in material of uniform cross-section is by controlled stretching, and Myer⁵⁰ *et al* have compared the efficiency of this process with that of cold forging and skin pass rolling, showing that it is considerably to be preferred. Mention is made of a 30 million pound stretcher being installed by one American company. With shaped products such as forgings, stretching is obviously impracticable and other methods of stress relief must be applied. Hill, Barker, and Willey⁵¹ have cooled quenched parts to -320° F in liquid nitrogen and then heated them rapidly in a steam blast, and they claim that, as this treatment is the reverse of quenching, stresses are reversed and largely cancelled out. Other approaches to the internal stress problem are those of Soja,⁵² who is concerned with the manufacture of aircraft structures. He contours wing panels by heating the panel stressed in a jig to about the precipitation treatment temperature; the jig is so designed that after cooling the panel assumes the form required. Soja's other technique is die quenching, a contoured die forcing the heated part into a cavity filled with metallic shot.

After every precaution has been taken in the semi-fabricating works, it is disastrous if corrosion or mechanical damage ruins metal products during transit. The Institute of Metals⁵³ informal discussion on economic protection and packaging during transport and storage is therefore timely and valuable, and the summarised discussion a fruitful source of advice on this subject.



An artist's impression of the 40,000 ton Orient Liner "Oriana," which has a welded aluminium super-structure using 1,000 tons of the metal.

Courtesy of Vickers-Armstrongs (Shipbuilders), Ltd.

The manufacture of airframes involves a good deal of sheet metal forming, and accounts of the methods used are not lacking. In small space, Vleck⁵⁴ has discussed many techniques employed by one aircraft company, including both shaping and joining. A point of special interest is that, to avoid distortion, sheet components are not quenched in baskets, but by "free fall," by dropping them into the quenching medium. Burnard⁵⁵ has also surveyed metal forming in the aircraft industry, including routing, chemical machining, stretch- and hydro-forming, and tube bending. He mentions shot forming, a technique involving the firing of steel shot at high speed from ranks of nozzles on a moving carriage. The use of this process by an American aircraft company⁵⁶ has been described; it is pointed out that the high cost of the equipment would limit its commercial application. Descriptions have been published⁵⁷ of recently introduced equipment for metal cutting and shaping, both foreign and domestic.

No completely successful simple test of deep-drawability has yet been discovered. Vassel⁵⁸ has investigated the Erichsen test, the Swift deep-drawing test, and a group of cup-drawing tests using flat-headed punches, and he finds that all are of some value. He also considers that the fundamental characteristics of the tensile test are indicative, including the true elongation and reduction of area.

The manufacture of metal containers, principally from tinplate and aluminium, involves many techniques of forming and joining. Panknin⁵⁹ has discussed these, including impact extrusion, drawing, and the making of the three-piece can. *Metal Progress* has devoted a large portion of one issue to a series of articles generally entitled "Overcoming the Producibility Barrier." Hawking⁶⁰ deals with tube bending, Broderick⁶¹ writes on rubber forming, Gaslt⁶² *et al* discuss chemical milling, Tesman⁶³ summarises hot extrusion, and there are also brief accounts of metal spinning⁶⁴ and of impact extrusion.⁶⁵ All papers are short, and all are concerned principally with efficient production. Together, they form the metal former's *vade mecum*.

Joining

The well-known jingle about the kingdom lost for the want of a horse-shoe nail has a special significance for the

engineer; joints are the vital parts of all his designs. Many methods are available for joining aluminium and its alloys, and much useful technical literature describing them is published each year. McDowell and Weeks,⁶⁶ in a general survey of resistance welding methods, particularly as applied in the manufacture of gas turbines, draw special attention to recent developments in available equipment. They also list conditions for the spot welding of aluminium alloys, and discuss the metallurgy of the welds obtained. The use of resistance welding in the lamp and valve industry has been described by Donelan,⁶⁷ and in a weldability chart illustrating which metals may be joined to each other, the only metal shown to be friendly to aluminium in this respect is silver.

A famous aircraft company has made over 50 million spot welds since 1951, and Gardner⁶⁸ has noted the methods used, and particularly the strict control of processes and quality and the necessary inspection procedures. Of 300,000 welds examined on the "Victor" prototypes, only 2-3% were judged defective. Turning, as the military are, from aircraft to missiles, Dawson⁶⁹ has discussed the advantages of roll-spot welding for attaching cylindrical parts in the manufacture of the "Jupiter" centre-section. Electrode pick-up was minimised by efficient cooling, and adjustment of wheel shape resulted in satisfactorily round spot welds. This work has no doubt contributed to the ability of rocket users to improve upon toxophilites and (on occasion) to shoot a missile in the air, and yet know where it falls to earth. High frequency resistance welding has been used in the U.S.A. for some time in the manufacture of tube from strip; a company in this country is now operating the equipment^{70, 71} and has made tubes in alloys N3, N4 and N5, as well as an aluminium-1% magnesium alloy, at speeds of 240 ft./min.

High frequency electrical energy converted to ultrasonic mechanical energy may be used to weld aluminium sheet and foil by introducing shear vibration between the parts to be joined, giving a solid-state metallurgical bond. Equipment up to 4,000 W. capacity is now available for the process, and has been described by Collins⁷² and his collaborators, who consider the method to have several advantages over resistance welding, including suitability for very thin material, simple surface preparation, lower power requirement, and ability to join dissimilar metals.

Jones and Potthoff⁷³ support these claims, and have compared some strength properties of ultrasonic welds with those of resistance welds. In sheet up to 0.071 in. thick, ultrasonic welds are stated to have higher shear and fatigue strengths, and to permit greater flexibility in joint design.

Recent progress in the welding of non-ferrous metals has been surveyed by Young,⁷⁴ and he provides a useful summary of the position reached with aluminium. In an interesting appendix, he lists no fewer than 29 current names for the inert gas metal arc process, and seven for the tungsten arc process; he deplores mildly the American terms MIG and TIG, and states a preference for two alternatives, both of which are, unfortunately, trade names. MIG and TIG may be undignified, but they have brevity and clarity on their side, all of which perhaps they gain from their parentage. The most important recent advance to which Young refers is the use of fine wires in MIG welding, and Tomlinson and King⁷⁵ have described the available equipment and its

applications, including operating conditions and weld properties for material thicknesses down to 0.036 in. This process was originally developed in America; McElrath⁷⁶ claims that in that country material as thin as 0.015 in. may be joined at high production speeds. Examples of the application of fine wire welding are given by this author, including fuel tanks and oil coolers. Jahn and Gourd⁷⁷ have investigated the possibilities of applying the I^2Rt principle to gas-shielded welding; with aluminium they find no measurable increase in burn-off rate and, indeed, no advantage in the welding of mild steel. Using cine films made during welding while the work was moved up and down relative to the electrode wire, Cresswell and Sherwood⁷⁸ studied the effect of rising output characteristic on the self-adjusting arc-welding of aluminium. Increase in power source slope increased self-adjustments but only up to 0.05 V./A., above which instability was encountered.

to be continued

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Hypereutectic Aluminium-Silicon Alloys

A Review of Published Information

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(Communication from The British Non-Ferrous Metals Research Association)

This article reviews published information on the effect of phosphorus, sodium and some other elements on the structure of the primary silicon and the eutectic matrix of hypereutectic aluminium-silicon alloys. The mechanical and physical properties are listed together with those of common piston alloys for comparison.

I. INTRODUCTION

UNTIL the discovery that certain metals, notably sodium, were capable of refining the aluminium-silicon eutectic structure, these alloys were considered to be of little general use owing to their poor mechanical properties. However, in the modified (or chill-cast) condition alloys containing up to about 13 wt.-% silicon (which corresponds to the eutectic composition in the modified alloys) have found wide application.

More recently the need for alloys combining low density, good wear resistance and low coefficient of expansion (as well as strength at operating temperatures) for use as piston materials in internal-combustion engines has led to the development of hypereutectic alloys containing up to 25 wt.-% silicon. These alloys require a treatment to refine the primary silicon, as otherwise it separates as large polyhedral crystals which segregate in the casting, have an adverse effect on mechanical properties, and cause poor surface finish and tool wear in machining.

The method commonly used to refine the primary silicon is to introduce phosphorus into the melt, and the various means of doing this which have been advocated in the literature are summarised in Section II. The nominal addition stated to produce maximum refinement varies considerably; the information is conflicting on whether this is due solely to differences in the efficiency of transfer (the refinement depending merely on the percentage of phosphorus present), or whether the refinement depends in other ways on the method used, e.g., on the particle size of the addition.

Although some authors claim to have found methods of refining both the primary and the eutectic silicon of a sand-cast hypereutectic alloy, their results are not always reproducible and are sometimes contradictory. In particular the published results summarised in Section II indicate that the action of sodium added to modify the eutectic is incompatible with that of phosphorus, so that only one form of silicon can be refined in a sand casting, depending on whether sodium or phosphorus is present in excess. Fortunately the eutectic may be partially refined by chill casting without the need for a sodium addition, and if the primary silicon is refined by adding phosphorus it is possible in a chill casting (e.g. a gravity die-cast piston) to obtain good properties from these

alloys. However, it is possible that the alloys may be used not only for pistons, but also for the crankcase-cylinder-block castings of engines; in such a casting, rate of cooling in thick sections would be relatively slow, and some other means of refining the eutectic may be desirable.

The properties of hypereutectic alloys of various compositions are reviewed in Section III, together with information on certain other alloys (mainly piston materials) for comparison. The extent to which mechanical properties at room and elevated temperatures vary with composition has not been investigated sufficiently to allow the effects of individual alloying additions and their optimum contents to be deduced. Furthermore, much of the information on properties relates to fully heat treated alloys, whereas for certain applications material in the as-cast or as-cast and aged or stabilised condition might be more economic.

II. STRUCTURE

A. Refining of Primary Silicon

Work on the refining of the primary silicon may be grouped as follows:

- (i) effect of sodium,
- (ii) effect of phosphorus and substances containing phosphorus,
- (iii) effect of sodium in conjunction with phosphorus, and
- (iv) miscellaneous methods.

(i) Effect of Sodium

According to Mascré,¹ the first effect of sodium (at approximately 0.05% sodium added) is to modify the eutectic structure and to make the primary silicon more dendritic. On increasing the sodium addition the primary silicon becomes coarser and more rounded, until at 1% added sodium the primary silicon is in the form of large spheroids. Terai² observed coarse rounded particles of primary silicon and a modified eutectic structure in a 22% silicon alloy to which 0.1 wt.-% sodium had been added. However, Neu³ is reported by Atterton to have found that sodium had no effect on the primary silicon but merely modified the eutectic. Wagner⁴ noted that sodium slightly refined the primary silicon. Although these observations are divergent, an examination of Table I shows that the alloys used were not of the same composition, and this might account in part for the differences.

* Issued to Members of the B.N.F.M.R.A. in July, 1959.

* Investigator, B.N.F.M.R.A., London.

(ii) Effect of Phosphorus

Mascré¹ observed that 0.005% phosphorus added as copper-phosphorus produced a microstructure showing fine equiaxial particles of primary silicon with a coarse eutectic, and that maximum refinement of the primary silicon occurred at 0.01% phosphorus added. Further increase in the amount of phosphorus (to 0.05% phosphorus added) had no more effect on the primary silicon but produced areas of extremely fine eutectic.

Neu⁵ reported that 0.05% phosphorus added had no refining effect on the eutectic structure and destroyed the tendency for a chill-cast alloy to form a fine eutectic. The following observations were made by Gürtler⁶: (i) on chill casting a hypereutectic alloy containing no phosphorus, the primary silicon was "feathery" and the direction of growth of the eutectic silicon was strongly influenced by the direction of the primary silicon; (ii) low phosphorus contents gave coarse polyhedral primary silicon; and (iii) higher phosphorus contents gave fine polyhedral primary silicon. Tsumura⁷ observed cavities at the centres of silicon crystals in alloys containing phosphorus, which he attributed to the pulling out of the nuclei during polishing. These features began to appear at 0.03 wt.-% phosphorus (added) in sand-cast alloys and 0.1 wt.-% phosphorus in chill-cast alloys. If the phosphorus addition in the form of copper-8% phosphorus was greater than 0.5 wt.-% phosphorus added, solid aluminium phosphide remained in the crucible.

Wagner⁴ agrees with Mascré¹ when prescribing the addition of 0.01% phosphorus as copper-phosphorus to give a structure showing fine, well dispersed primary silicon but states that the method is not so satisfactory for sand castings. Terai,² adding phosphorus as copper-4% phosphorus obtained maximum refinement and tensile strength in a 22% silicon alloy with an addition of 0.006 wt.-% phosphorus—larger additions had no further effect. He noted also that maximum refinement was attained after a holding time of 20–30 mins. when the melt temperature was below 850° C., but that at a higher temperature (920° C.) the structure coarsened rapidly if the melt was held at this temperature for more than 5 mins. after the phosphorus addition. Also, the primary silicon became coarser as the casting temperature increased above 840° C., or the mould temperature above 200° C., or after three successive remelts. Onitsch-Modl⁸ suggested that copper-phosphorus partly refined the eutectic as well as the primary silicon.

The inadvisability of introducing phosphorus as copper-phosphorus has been mentioned by many workers—the main objections being the large percentage of copper simultaneously introduced and the difficulty with which the copper-phosphorus dissolves in the melt. A more direct method was suggested by Thury and Kessler,⁹ who used a metallothermic mixture of aluminium and a phosphorus compound ("Phoral") to produce very fine particles throughout the melt. They recommended also that chlorine treatment should be used after the addition to improve the refinement and to enable a lower treatment temperature to be used—750° instead of 800° C.

Kessler and Winterstein¹⁰ in a paper stressing the influence of the grain size of the refining agent on the degree of refinement of the primary silicon suggest the use of the following mixture:

TABLE I.—ALLOYS USED BY MASCRÉ,¹ NEU,⁵ WAGNER⁴ AND TERAI²

Investigator	Composition (%)										Total Impurities
	Si	Fe	Cu	Zn	Mg	Mn	Pb	Ni	V		
Mascré	18-23	< 0.8	1-3	< 0.03	< 0.1	< 0.1	< 0.1	< 0.1	—	< 0.2	
Neu	30	—	—	—	—	—	—	—	—	—	
Wagner	32	0.5	1	—	1	—	—	2	0.1	—	
Terai	22	—	—	—	—	—	—	—	—	—	

Red phosphorus 20%
Potassium chloride 70%
Potassium titanofluoride 10%

ground together to 20–60 μ and added in amount 0.65–0.80% of melt weight; this method has been patented.¹¹ They claim that this reagent, finely ground, gave fine eutectic and fine, well distributed primary silicon. Again the process was said to be enhanced by a subsequent chlorine treatment.

The addition of phosphorus directly as aluminium phosphide is the subject of an Aluminiumwerke Nürnberg Patent¹² which claims that the resulting primary silicon particles are from 0.02–0.04 mm. in size. Neu¹³ published the use of a mixture of hexachlorethane and red phosphorus to refine the primary silicon. This method has been used¹⁴ to refine a complex 24% silicon alloy with considerable success, although the eutectic was coarser in the refined alloy. Koritta and Franek¹⁵ recommend 0.45 wt.-% phosphorus pentachloride added at ~800° C. for optimum refinement of a 20% silicon-aluminium alloy, whereas Kissling and Tichy¹⁶ added only 0.01% phosphorus to refine a complex 21% silicon alloy.

(ii) Effect of Sodium in Conjunction with Phosphorus

Mascré¹ added 0.01% phosphorus, which he had found to give maximum refinement of the primary silicon, together with sodium in increasing amounts. He observed that the eutectic was fully modified by the sodium and the shape of the primary silicon varied with the sodium content as detailed above for additions of sodium alone, although the primary silicon particles were much finer. Neu,⁵ however, found that sodium nullified the effect of the added phosphorus on the primary silicon and fully modified the eutectic. Löhberg¹⁶ reported dendritic primary silicon on adding 0.01% phosphorus and 0.2% sodium.

Terai² found little adverse effect when 0.005% sodium was added to 22% silicon alloy treated with 0.005% phosphorus, but that 0.1% sodium markedly coarsened the primary silicon. Adding excess sodium to a phosphorus bearing alloy, Tsumura⁷ observed larger and more rounded primary silicon which contained phosphide nuclei similar to those in the sodium-free alloys, despite the formation of a modified eutectic structure.

(iv) Miscellaneous Treatments

Neu⁵ was able to modify the eutectic by the addition of 2% magnesium and claimed that the addition of not less than 0.3% magnesium and 0.4% phosphorus together refined both the primary silicon and the eutectic. However, others have observed that complex alloys containing up to 1% magnesium had coarse eutectic structures when the primary silicon was refined with phosphorus. Furthermore, Thury and Kessler⁹ found that magnesium phosphide was quite ineffective in refining the primary silicon. Neu¹³ tried also titanium, boron and calcium without producing refinement.

TABLE III.—SUMMARY OF REPORTED METHODS OF REFINING HYPEUTECTIC ALLOYS.

Method involving Addition of :	Reported by :	Amount Added (%)	Effect on Chill-Cast Microstructure	
			Primary Silicon	Eutectic
(1) Sodium	(a) Mascré ⁽ⁱ⁾	0.05 Na	Dendritic	Well modified
		0.20 Na	Coarser and more rounded	Well modified
		1.0 Na	Coarser and spheroidal	Well modified
	(b) Neu ⁽ⁱⁱ⁾	2 salts	No effect	Well modified
	(c) Wagner ⁽ⁱⁱⁱ⁾	(?)	Slightly refined	Well modified
(2) Phosphorus Pentachloride (i)	(d) Tera ⁽ⁱ⁾	0.1 Na	Coarser and more rounded	Well modified
	(a) Used previously	1.0 PCl ₅	Refined, but results variable owing to P losses	Coarse
	(b) Koritta & Franek ^(iv)	0.43 PCl ₅	Refined	Coarse
(3) Copper-Phosphorus (ii)	(c) Onitech-Mod ^(v)	0.1 PCl ₅	Refined	Coarse
	(a) Mascré ⁽ⁱ⁾	0.005 P	Fine polyhedral	Coarse
		0.01 P	Maximum refinement	Coarse
		0.08 P	Fine polyhedral	Some areas very fine
	(b) Neu ⁽ⁱⁱ⁾	0.05 P	Fine polyhedral	Coarse
	(c) Wagner ⁽ⁱⁱⁱ⁾	0.01 P	Fine well dispersed	Coarse
	(d) Tera ⁽ⁱ⁾	0.006 P	Maximum refinement (0.02 mm. diameter)	Coarse
(4) "Phoral" (iii)	(e) Onitech-Mod ^(v)	0.1-1.0 Cu (?) P	Fine well dispersed	Moderately refined
	Thury & Kessler ^(v)	1.0 Phoral	Fine well dispersed	Coarse
(5) "Alphosit" (iv)	Kessler & Winterstein ^(vi)	0.65-0.80 Alphosit	Fine well dispersed	Coarse
(6) Aluminium Phosphide (v)	Aluminiumwerke Nürnberg ^(vii)	0.8-1.0 AlP	Fine (0.02-0.04 mm. diameter)	Coarse
(7) Hexachlorethane + Red Phosphorus	Neu ⁽ⁱⁱ⁾		Fine	
(8) Sodium + Phosphorus	(a) Mascré ⁽ⁱ⁾	0.01 P + Na	Medium fine becoming coarser and globular with increasing sodium	Well modified
	(b) Neu ⁽ⁱⁱ⁾		Sodium nullifies the effect of phosphorus	Modified
	(c) Löhberg ^(viii)	0.01 P + 0.2 Na	Dendritic	Modified
	(d) Tera ⁽ⁱ⁾	0.005 P + 0.005 Na	Fine (0.02 mm. diameter)	Coarse
		0.005 P + 0.1 Na	Coarser (0.06 mm. diameter)	Modified
(9) Magnesium	Neu ⁽ⁱⁱ⁾	2.0 Mg.	No effect	Modified
(10) Magnesium + Phosphorus	(a) Neu ⁽ⁱⁱ⁾	≥ 0.3 Mg + ≥ 0.4 P	Very fine dispersal	Well modified
	(b) Thury & Kessler ^(v)		No effect	
	(c) Tera ⁽ⁱ⁾	0.005 P + 0.1-2.0 Mg	Size increased from 0.02-0.08 mm. diameter with increasing Mg content	
(11) Others	(a) Neu ⁽ⁱⁱ⁾	Ti	No effect	Partly refined
	(b) Onitech-Mod ^(v)	0.5 Ti	Variable results	
	(c) Neu ⁽ⁱⁱ⁾	B	No effect	
		Ca	No effect	
	(d) Tera ⁽ⁱ⁾	0.005 P + 0.05 As	Additional refinement (0.02-0.01 mm. diameter)	
		0.005 P + 0.05 B	" " " "	
		0.005 P + 0.05 Be	No finer than with P alone	
		0.005 P + 2.0 Cd	" " "	
		0.005 P + 2.0 Co	" " "	
		0.005 P + 1.0 Cr	" " "	
		0.005 P + 4.5 Cu	Additional refinement (0.02-0.01 mm. diameter)	
		0.005 P + 1.0 Fe	No finer than with P alone	
		0.005 P + 1.0 Mn	" " "	
		0.005 P + 0.15 Ti	" " "	
		0.005 P + 2.0 Zn	" " "	
	(e) Onitech-Mod ^(v)	Silumin + Al chips (1:1) followed by Na	Very fine	Fine

(i) Unpleasant fumes; hygroscopic.

(ii) The copper introduced is not always desirable. Tera found maximum effect after 20-30 minutes holding below 850° C.

(iii) Improved by subsequent chlorine treatment.

(iv) The refinement is improved by reducing the grain size of Alphosit. Improved by subsequent chlorine treatment.

(v) Followed by or in conjunction with chlorine treatment.

TABLE II.—EFFECT OF ADDITIONAL ELEMENT ADDED WITH PHOSPHORUS ON THE SIZE OF THE PRIMARY SILICON (TERAI¹)

Additional Element	Amount Added (wt.-%)	Size of Primary Silicon (mm.)
None	—	0-02
As	0-005-0-05	0-02-0-01
B	0-005-0-05	0-02-0-01
Be	0-005-0-05	0-02-0-02
Cd	0-10-2-50	0-02-0-02
Co	0-10-2-50	0-02-0-02
Cr	0-10-1-00	0-02-0-02
Cu	0-10-4-50	0-02-0-01
Fe	0-10-1-00	0-02-0-02
Mn	0-10-1-00	0-02-0-02
Mg	0-10-2-00	0-02-0-08
Na	0-005-0-100	0-02-0-06
Ti	0-01-0-15	0-02-0-02
Zn	0-10-2-00	0-02-0-02

Increasing the magnesium content from 0.1-2.0 wt.-% in a 22% silicon alloy treated with 0.005% phosphorus. Tera¹ observed an increase in primary silicon size from 0.02-0.08 mm. In conjunction with 0.005% phosphorus, Tera¹ added several other elements to a 22% silicon alloy and obtained the results shown in Table II, from which it appears that arsenic, boron and copper slightly assist in refining the primary silicon; magnesium and sodium hinder; and beryllium, cadmium, cobalt, chromium, iron, manganese, titanium and zinc have no effect in the quantities shown. Tsumura⁷ noted that antimony combined preferentially with phosphorus when added to a phosphorus-treated alloy.

Onitsch-Modl⁸ suggests the addition of a 1:1 mixture of silumin and aluminium chips to give fine primary silicon followed by sodium to modify the eutectic. The effect of chlorine degassing after treatment is thought to be beneficial by most workers, but Wagner⁴ stated that fluxes and degassers had no effect when the phosphorus was added as copper-phosphorus. Neu⁵ observed a decrease in tensile strength if the melt was degassed after treatment with magnesium and phosphorus. The various suggested treatments for refining the hyper-eutectic alloys are summarised in Table III.

A comparison of the crystal forms of silicon and aluminium phosphide (see Table IV) suggests that the marked influence exerted by additions of phosphorus on the particle size of primary silicon and, as described below, on the undercooling of this phase, can be attributed to aluminium phosphide particles which act as nuclei for the solidification of silicon crystallites. It follows, therefore, that sodium acts upon the aluminium phosphide in such a way that these particles are no longer capable of nucleation, presumably by preferential formation of a sodium phosphide or a complex compound.

B. Modification of the Eutectic

The binary eutectic in the aluminium-silicon system occurs at 11.7 wt.-% silicon and 577° C., and usually forms as coarse silicon plates or needles in a continuous matrix of a solid solution containing 1.65 wt.-% of dissolved silicon. The eutectic structure can be modified by chill-casting or by the addition of small quantities of certain metals (notably sodium) or salts containing these metals. The eutectic point is displaced to a higher silicon content by either method of modification.

Although modification has been known and practised for many years, its mechanism has not been fully explained. Gayler¹⁷ showed that the solubility curves of modified alloys were similar to the super-solubility curves of unmodified alloys, and Archer and Kempf¹⁸ showed

TABLE IV.—COMPARISON OF THE CRYSTAL FORMS OF SILICON AND ALUMINIUM PHOSPHIDE¹

Phase	Lattice Type	Lattice Constant	Shortest Atomic Distance
Si	Diamond (A.4)	5.42	2.44 (Si-Si)
AlP	Zinc blend (B.3)	5.45	2.56 (Al-P)

that satisfactory modification depended on a definite sodium content of the melt at the time of casting. Scheil and Zimmermann¹⁹ found a ternary phase identified as AlNaSi₄, but stated that free sodium was responsible for modification. Ransley and Neufeld²⁰ attributed the formula AlNaSi_{1.25} or AlNaSi_{1.33} to the ternary phase; they found a ternary eutectic at about 0.017 wt.-% sodium, which value agrees remarkably well with the practical observation that the tensile properties of a eutectic aluminium-silicon alloy attain maximum value and the structure a maximum refinement when the residual sodium content is 0.017 wt.-%. Baker²¹ observed sustained undercooling about 9° C. below the equilibrium eutectic temperature throughout the solidification of a modified silicon alloy. Thall and Chalmers²² noted that sodium lowers the temperature of eutectic solidification but has no effect on the temperature of primary solidification or on the melting point of the eutectic. By filtering an unmodified melt before casting, Klaiber²³ obtained a fine lamellar eutectic on slow cooling when the phosphorus content of the alloy was less than 0.00015%. Gürtler⁴ extended this work by determining the effect of cooling rate on the structure of (i) an initially lamellar 13% silicon alloy (i.e. low in phosphorus), and (ii) an initially coarsely crystalline 13% silicon alloy (i.e. high in phosphorus). His results showed that whereas (i) gave aluminium-solid-solution dendrites and a fine modified eutectic on chill-casting, (ii) gave primary silicon and a much coarser granular eutectic. Similarly, Schultz²⁴ found that an initially lamellar (low phosphorus) alloy required less sodium to form a fully modified structure than did an initially granular (high phosphorus) alloy. In studying undercooling phenomena, Löhberg¹⁶ showed that the degree of undercooling on increasing the rate of cooling was governed by the phosphorus content. With unmodified alloys containing phosphorus, the eutectic temperature was not lowered appreciably even at high cooling rates, but with a low-phosphorus or a sodium-modified melt considerable undercooling was possible and a modified structure resulted. The work of Tera² gave similar results for the undercooling of the eutectic in 22% silicon aluminium-silicon alloys treated with sodium and phosphorus (Table V).

Recently, Joyce²⁵ obtained similar results with a hypereutectic binary alloy and noted further that the undercooling of the eutectic was sustained in the modified alloys. Tsumura⁷ showed that at high cooling rates

TABLE V.—EFFECT OF SODIUM AND PHOSPHORUS ADDITIONS AND COOLING RATE ON THE UNDERCOOLING OF THE LIQUIDUS AND THE EUTECTIC IN A 22 WT.-% SILICON ALUMINIUM-SILICON ALLOY. (TERAI¹)

	Addition	Rate of Cooling (° C./min)		
		8	80	120
Degree of Undercooling of Eutectic (° C.)	None	2	3	12
	Phosphorus	2	2	4
	Sodium	7	15	27
Degree of Undercooling of Liquidus (° C.)	None	0	3	5
	Phosphorus	0	0	4
	Sodium	2	4	10

TABLE VI.—COMPARISON OF THE WEAR PROPERTIES OF VARIOUS CYLINDER BORE MATERIALS. [SMITH.²⁴]

Bore Material	Duration of Test (hr.)	Average Wear at Top of Ring Travel (in./100 hr.)
Iron Plate on 356-T7 Alloy (LM8)	119	0.00405
0.0015 in. Chromium Plate on 356-T7 Alloy (LM8)	134	0.00462
Standard Cast Iron	684	0.00070
0.005 in. Molybdenum Sprayed on 356-T7 Alloy (LM8)	457	0.00060
Uncoated 356-T7 Alloy (LM8)	128	0.00055
Uncoated High-Silicon Alloy	227	0.00038

(~6,000° C./min.) the eutectic was fully modified in the absence of sodium and at slow cooling rates (1.3° C./min.) the eutectic was unmodified in a sodium treated alloy even though crystals of NaAlSi₄ were present in the microstructure.

Various theories^{22, 24, 28-33} have been advanced to account for the above observations, but the mechanism of modification is not yet completely understood. It is not intended here to summarise these theories. The following mechanism of eutectic and primary solidification is put forward tentatively as a possible explanation of the observed phenomena.

When a hypereutectic aluminium-silicon alloy is slowly cooled in the absence of deliberately introduced nuclei, crystallites of silicon form just below the liquidus temperature from stray particles in the melt. These crystallites grow rapidly as the temperature falls and produce a structure containing coarse primary silicon crystals. The eutectic will solidify in the coarse unmodified form. If particles capable of nucleating the primary silicon (e.g. AlP) are abundant in the melt, many crystallites will be formed at the liquidus temperature

and fine primary silicon crystals will result. Although such nuclei should be capable of nucleating eutectic silicon also, the number of nuclei required for what would be considered effective refinement of the eutectic particles would be far greater than for the primary silicon, and the eutectic has a coarse structure even under these conditions of solidification.

On fast cooling a phosphorus-free melt the refinement of the primary silicon is only slight owing to the high growth rate of the crystallites once they are formed from the undercooled liquid. The dependence of the growth of the eutectic upon diffusion combined with the rapidity of extraction of the latent heat of solidification from the casting causes sustained undercooling of the eutectic, which allows repeated homogeneous nucleation throughout solidification, and a finer eutectic structure is obtained. If nuclei are present the primary silicon is refined as described above for slow cooling, but the phosphorus hinders the undercooling of the eutectic (possibly by partial nucleation of the silicon) and the eutectic structure produced is coarser than that obtained by chill casting a phosphorus-free melt.

The presence of sodium in the melt first of all renders ineffective any phosphorus which may be present (possibly by the preferential formation of sodium phosphide or some more complex compound instead of aluminium phosphide) thus causing the primary silicon to be coarse. Secondly, the eutectic is observed to undercool considerably more, even at slow cooling rates; this would further encourage the repeated nucleation of silicon and produce a finer eutectic structure. The mechanism of this effect is the subject of much controversy, but it seems possible that the silicon particles, once formed, are coated with a sodium-rich layer which

TABLE VII.—TYPICAL COMPOSITIONS OF SOME PISTON ALLOYS AND HYPEREUTECTIC ALUMINIUM-SILICON ALLOYS.

Alloy	Composition (%)										Others
	Si	Cu	Mg	Fe	Mn	Ni	Zn	Pb	Sn	Ti	
A. BRITISH ALLOYS*											
LM12	<2.0	10.0	0.25	1.0	<0.6	<0.5	<0.1	<0.1	<0.1	<0.1	Mn + Fe 1.5 max + Nb <0.2 <0.2 + Nb <0.17
LM13 (Lo-ex) .. .	12.0	0.9	1.1	<0.8	<0.5	2.5	<0.1	<0.1	<0.1	<0.1	
LM14 ("Y" alloy) .. .	<0.6	4.0	1.5	<0.6	<0.6	2.0	<0.1	<0.05	<0.05	<0.2	
LM15	1.3	2.1	1.1	1.1	<0.1	1.3	<0.1	<0.05	<0.05	<0.17	
B. AMERICAN ALLOYS APART FROM THOSE WITH BRITISH EQUIVALENTS (See Footnotes)											
D122	0.5	2.0	1.0	<1.2	<0.5	1.0	<0.5			<0.2	Total = 0.5 0.25 Zr 0.10 V
254	—	—	6.0		1.0	1.5					
254 (Special)		1.5	6.0		1.0						
A355	5.0	1.4	0.5		0.8	0.8					
356	7.0		0.3								
Smith ²⁴	20.0	2.0	1.0		0.5						
U.S. Pat. 2357, 449-452 ²³ .. .	21.0	1.6	0.7		0.5	0.4					
C. FRENCH ALLOYS											
A-820-U	20.0	2.0	<0.1	<0.8	<0.1	<0.1	<0.05	<0.05	<0.05	<0.1	
D. GERMAN ALLOYS											
Nitral 1761	17.0	1.0	1.0	<0.8	0.5	3.4	<0.2			<0.2	Cr 0.5 Cr 0.5
Nitral 2361	23.5	1.0	1.0	<0.8	<0.2	0.9	<0.2			<0.2	
Mahle 138	18.0	1.0	1.0			1.0					Co 0.5
Mahle 244 (K.S.282) .. .	25.0	1.0	1.0			1.0					
K.S.280	21.0	1.5	0.5	<0.7	0.7	1.5	<0.2			<0.2	Cr 1.1; P 0.005; Be 0.005; Cd 0.8
K.S.281	20.0	1.5	1.5	<0.7	0.5	<0.5	<0.2				
K.S.245	14.0	4.5	0.7		1.0	1.5					
K.S. Alusil	20.0	1.8				0.5					
E. JAPANESE ALLOY											
Japanese (Terai) ²	22.0	2.8	0.6			0.9				<0.2	

* RELATED ALLOYS

	Alcoa	Alcan	A.S.T.M.	S.A.E.
LM12	122	250	C.G.100A	34
LM13 (Lo-ex)	A.132	162	S.N.122A	521
LM14 ("Y" alloy)	142		C.N.42A	39

hinders their growth²⁰; alternatively it has been suggested that the presence of sodium alters the interfacial (or dihedral) angles in such a way that silicon crystallites are constantly enveloped by solid solution.²²

III. PROPERTIES

A. Mechanical Properties of As-cast Alloys at Room Temperature

The high-silicon alloys are important by virtue of their low coefficient of expansion and high wear resistance—factors which are desirable in such engine components as pistons and cylinders. The superior wear properties of high silicon alloys when used for cylinder bores are shown in Table VI (Smith²⁴).

The tensile properties of the binary alloys in the unrefined condition are poor. Archer and Kempf¹⁸ and Terai² have shown that in the sand-cast and unmodified alloys the tensile strength increases with silicon content to a maximum of about 10 tons/sq. in. at the eutectic composition and then falls off rapidly with the appearance of coarse primary silicon particles in the structure to a value of ~4 tons/sq. in. at 22% silicon. The elongation of these alloys decreases continuously with increasing silicon content (except for a slight rise at the eutectic

composition) and is very small above 18% silicon. In a complex alloy containing 0.77% magnesium, 0.58% manganese, 1.66% copper, 0.65% iron, 0.37% nickel, refined with phosphorus, Kissling and Tichy²⁵ observed a decrease in tensile strength from 17.9 tons/sq. in. to 6.7 tons/sq. in. with increase in silicon content from 10% to 25% in the chill-cast and aged condition. The strength of fully heat treated alloys was about 2 tons/sq. in. higher.

To improve the tensile properties of the hyper-eutectic alloys two methods are available: (i) refinement of the primary silicon particles and, (ii) additions of other alloying elements. On refining a 20% silicon alloy with phosphorus, Smith²⁴ noted a 20% increase in the tensile strength in the sand-cast alloy and a 5% increase in the chill-cast alloy. Terai² raised the tensile strength from 4.5 tons/sq. in. to 9 tons/sq. in. by adding 0.006% phosphorus to a 22% silicon binary alloy. Since the strength thus attained is the tensile strength of the eutectic matrix (which is coarse in the phosphorus-treated alloy), it appears that (in the absence of a method of modifying the eutectic of the phosphorus-treated alloys) further increase in strength can be obtained only by adding elements which can strengthen the solid-solution phase. Such elements as copper and magnesium

TABLE VIII.—MECHANICAL PROPERTIES OF SOME PISTON ALLOYS AND HYPEREUTECTIC ALUMINIUM-SILICON ALLOYS AT ROOM TEMPERATURE

Alloy	Condition	Tensile Strength (tons/sq. in.)	0.1% Proof Stress (tons/sq. in.)	Elongation (% on 2 in.)	Hardness (Brinell)
LM12	s/c	7-9	5-7	0-0.5	70-80
	c/c	11-13	8-10	0.5-1.5	80-90
	s/c WP	13-16	11-13	0-0.5	100-150
	c/c WP	18-22	15-19	0-0.5	100-150
LM13	s/c WP	11-13	12	0-5	100-150
	c/c WP	16-19	17	0-5	100-150
	s/c WP(S)	9			65-85
	c/c WP(S)	13			65-85
LM14	s/c WP	14-16	13-14	0.5-1.0	100-150
	c/c WP	18-20	14-16	1.0-3.0	100-150
	s/c WP(S)	12			75-85
	c/c WP(S)	15			75-85
LM15	s/c WP	18-19	17	1.0	100-150
	c/c WP	21-23	21 (0.2%)	2.0	100-150
D132 (U.S.A.)	c/c P	16	12.5	1.0	105
Smith ²⁴ (U.S.A.)	Unrefined s/c	8-0		~0.5	85
	Unrefined s/c P	9-5		~0.5	90
	Unrefined s/c WP	12-5		~0.5	120
	Unrefined c/c	9-5		~0.5	85
	Unrefined c/c P	11-5		~0.5	90
	Unrefined c/c WP	14-5		~0.5	120
	Refined s/c	12-0		~0.5	115
	Refined s/c P	13-5		~0.5	120
	Refined s/c WP	17-5		~0.5	130
	Refined c/c	13-5		~0.5	115
	Refined c/c P	14-5		~0.5	120
	Refined c/c WP	18-5		~0.5	130
	s/c M	9-7		0-1.0	76
	s/c P	10-1		0-1.0	90
	c/c M	11-3		0-1.0	87
	c/c P	14-3		0-1.0	102
U.S. Pat. 2357, 449-452 ²²	c/c WP	17-0		0-1.0	116
	d/c M	15-7		0-1.0	115
A-S20-U (French)	c/c	11-12	8-9.5	0-5	85-90
	c/c WP	12-14.5		0.3-0.8	90-140
	c/c WP	11-5-14.0		0.1-0.3	90-125
Niral 1761 (German)	c/c				130-140
Niral 2361 (German)	c/c				90-100
Japanese alloy ⁸	c/c	11-13			100-110
	c/c P	12-15			110-115
	c/c WP	18-20			130-140
	c/c O	10-11			90-100
Cast Iron		13.5-14.5			179-228

s/c = sand-cast.
c/c = chill-cast.
d/c = die-cast.

W = solution heat treatment.
P = precipitation heat treatment.

(S) = special stabilizing treatment.
O = annealed.

achieve this aim and make the alloy susceptible to further improvement by heat treatment, as noted below. Terai² observed in ternary alloys a maximum tensile strength of 12.8 tons/sq. in. at 4% copper and 12.4 tons/sq. in. at 1.25% magnesium, while by adding 2.5% copper with 1.2% magnesium the strength was raised to 13.5 tons/sq. in.

The composition of some commercial and experimental hypereutectic silicon alloys are listed in Table VII, and their room temperature mechanical properties, where available, are listed in Table VIII. The compositions and properties of existing British and U.S.A. piston alloys and of a typical cast iron—used for cylinder block castings—are included in the tables for comparison.

B. Effect of Heat Treatment

No data are available on the effects of heat treatment on the properties of binary hypereutectic silicon alloys. Archer, Kempf and Horn²⁶ studied the effect of various heat treatments on the hypoeutectic and eutectic binaries and reached the following conclusions :—

- (i) Forty hours at 565° C. and water quenched (in about $\frac{1}{4}$ in.-thick section) :

(a) the tensile strength of unmodified alloys is increased ;

(b) the tensile strength of modified alloys is unchanged at 5% and 14% silicon but decreased for intermediate silicon contents ;

(c) elongation is increased in both modified and unmodified alloys up to the normal eutectic composition.

(ii) A short-time treatment at ~565° C. followed by quenching favours a solution effect, whereas a longer time at this temperature favours the spheroidisation of the silicon. The strength and hardness are improved by the solution effect and the ductility by the spheroidising effect.

(iii) Improvement in properties, especially of modified alloys, was obtained by quenching while the casting cooled after solidification.

The available results for the properties obtained by heat treating some commercial high-silicon alloys are included in Table VIII. The solution and precipitation treatments employed are similar to those used for alloys of lower silicon contents, since these complex alloys con-

TABLE IX.—HIGH-TEMPERATURE PROPERTIES OF SOME PISTON

Alloy	Condition	Reference	Soaking Time at Testing Temperature (hr.)	20° C.				100° C.				150° C.			
				T.S. (tons/sq. in.)	0.2% P.S. (tons/sq. in.)	Elong. (% on 2 in.)	BHN	T.S. (tons/sq. in.)	0.2% P.S. (tons/sq. in.)	Elong. (% on 2 in.)	BHN	T.S. (tons/sq. in.)	0.2% P.S. (tons/sq. in.)	Along. (% on 2 in.)	BHN
122	s/c O	37	10,000	12.0	8.9	0.0	—	11.8	8.4	0.0	—	11.1	7.6	0.0	—
	s/c WP	37	10,000	17.9	13.4	0.0	—	17.4	13.0	0.0	—	15.5	12.2	1.0	—
	c/c P	37	10,000	16.6	15.6	0.0	—	16.5	14.5	0.0	—	14.7	12.9	0.5	—
	c/c 20 hr. at 170° C.	37	10,000	15.2	—	0.0	—	14.7	—	0.0	—	13.8	—	1.0	—
LM12	c/c WP	38	Unknown	22.5	—	—	—	23.0	—	—	—	22.0	—	—	—
	c/c P	38	Unknown	22.5	—	—	—	23.0	—	—	—	22.0	—	—	—
A132	s/c P	37	10,000	11.4	11.4	0.0	—	11.2	10.5	0.0	—	11.2	9.6	0.5	—
	s/c 6 hr. at 516° C., B.W.Q., 8 hr. at 327° C.	37	10,000	15.4	13.8	0.0	—	12.5	10.9	0.0	—	10.2	9.0	0.0	—
	s/c 9 hr. at 516° C., B.W.Q., 11 hr. at 170° C.	37	10,000	16.5	—	0.0	—	15.3	—	0.0	—	13.3	—	0.5	—
	c/c P	37	10,000	16.8	13.6	0.0	—	18.0	11.9	1.0	—	14.4	10.3	1.5	—
LM13 (Lo-ex)	c/c WP	38	Unknown	21.5	—	—	—	21.0	—	—	—	20.0	—	—	—
	c/c WP	2	Unknown	21.6	—	—	130	21.0	—	—	121	—	—	—	—
142	s/c M	37	10,000	13.5	12.5	0.0	—	13.4	13.4	0.0	—	13.4	12.5	0.0	—
	s/c O	37	10,000	12.0	8.0	0.5	—	12.0	8.0	0.5	—	12.0	8.0	0.5	—
	s/c W(S)	37	10,000	12.5	11.1	1.5	—	11.8	10.4	1.5	—	11.2	9.6	1.5	—
	s/c WP	37	10,000	16.5	14.3	0.0	—	14.7	13.3	0.0	—	12.4	12.5	0.0	—
LM14 (Y Alloy)	s/c WP	38	1	16.5	15.4*	0.3	113	16.8	15.3*	0.6	94.8	15.2	14.6*	0.3	100
	s/c 2 hr. at 527° C., B.W.Q., 1 hr. at 232° C., 2 hr. at 288° C.	37	10,000	15.2	—	0.0	—	14.9	—	0.0	—	14.5	—	0.0	—
142	c/c P	37	10,000	17.9	15.5	1.0	—	17.6	15.2	1.0	—	16.5	14.7	1.0	—
	c/c 44 hr. at 170° C.	37	10,000	18.0	16.6	0.0	—	17.8	15.6	0.5	—	16.8	15.5	1.0	—
	c/c WP	2	Unknown	20.4	—	—	108	19.8	—	—	97.0	—	—	—	—
	c/c WP	2	Unknown	22.3	—	—	134	22.1	—	—	125	—	—	—	—
D132	c/c WP	2	Unknown	22.3	—	—	134	22.1	—	—	125	—	—	—	—
	c/c WP	34	—	18.2	—	—	130	—	—	—	—	13.8	—	—	—
Smith—U.S. Pat. 2257-449-452	c/c P	35	1	14.3	—	—	—	14.1	—	—	—	13.7	—	—	—
	c/c WP	35	1	17.0	—	—	—	16.8	—	—	—	15.7	—	—	—
K.S.280	c/c WP	2	Unknown	15.9	—	—	148	15.2	—	—	135	—	—	—	—
	c/c WP	39	Unknown	13.5	—	—	105	13.7	—	—	105	—	—	—	—
Nital 1761	c/c WP	39	Unknown	12.7	—	—	108	12.4	—	—	100	—	—	—	—
	c/c WP	39	Unknown	12.7	—	—	108	12.4	—	—	100	—	—	—	—
Nital 2361	c/c WP	39	Unknown	12.7	—	—	108	12.4	—	—	100	—	—	—	—
	c/c WP	39	Unknown	12.7	—	—	108	12.4	—	—	100	—	—	—	—
Japanese Alloy	c/c P	2	Unknown	14.6	—	—	110	14.6	—	—	110	—	—	—	—
	c/c WP	2	Unknown	20.3	—	—	150	19.7	—	—	144	—	—	—	—

T.S. = tensile strength
P.S. = proof stress
BHN = Brinell hardness number

/c = sand-cast
sc/c = chill-cast
M = as-cast

tain other elements such as copper and magnesium which make them susceptible to such treatments.

C. Properties at Elevated Temperatures

The available information on the high-temperature properties of the hypereutectic alloys is summarized in Table IX. Values for the common piston alloys of lower silicon content are also included for comparison. Work³⁷ on the influence of prolonged heating on the properties of the latter materials has shown that the effects of heat treatment are retained even after long periods at 250° C. This temperature is higher than would be experienced in service if the alloys were used for cylinder blocks or liners, and heat treatment would therefore be a useful tool for improving the properties of the high-silicon alloys in these applications if it were economical.

D. Thermal Properties

Data on the thermal expansion and conductivities of some piston alloys and hypereutectic aluminium-silicon alloys are shown in Table X. The values for cast iron are given as a comparison. The coefficient of expansion decreases linearly with increase in silicon content.³⁸ For

the particular alloy developed by Terai² the coefficient of linear expansion is lower in the chill-cast and aged conditions than in either the as-cast or fully heat treated conditions. The thermal conductivities of the aluminium-silicon alloys are lower than for LM12, 14 and 15, but the conductivity of a hypereutectic alloy³⁴ is considerably improved by refinement and heat treatment.

E. Dimensional Stability

Very little information has been published on the dimensional stability of the hypereutectic aluminium-silicon alloys. Kissling and Tichy³⁵ have shown that the permanent growth of a complex 21% silicon alloy in a given time and temperature is dependent on the previous history of the test-piece as for other aluminium alloys. In the chill-cast condition at 200° C. the growth increased from 0.000137 to 0.000381 in./in. as the time at this temperature was increased from 2 to 72 hours. Permanent growth could be eliminated by heat treatment only at the expense of a reduction in tensile strength. Terai¹² observed permanent shrinkage of a complex 22% silicon alloy in the chill-cast and aged condition after heating for 5 hours at 350° C.

ALLOYS AND HIGH SILICON ALUMINIUM ALLOYS

200° C.				250° C.				300° C.				350° C.				400° C.				Reference
T.S. (tons/ sq. in.)	0.2% P.S. (tons/ sq. in.)	Elong. (% on 2 in.)	BHN	T.S. (tons/ sq. in.)	0.2% P.S. (tons/ sq. in.)	Elong. (% on 2 in.)	BHN	T.S. (tons/ sq. in.)	0.2% P.S. (tons/ sq. in.)	Elong. (% on 2 in.)	BHN	T.S. (tons/ sq. in.)	0.2% P.S. (tons/ sq. in.)	Elong. (% on 2 in.)	BHN	T.S. (tons/ sq. in.)	0.2% P.S. (tons/ sq. in.)	Elong. (% on 2 in.)	BHN	
10-0	6-7	0-0	—	8-0	5-4	2-0	—	5-6	3-1	10-0	—	—	—	—	—	—	—	—	—	37
11-1	7-8	2-0	—	5-6	2-7	6-0	—	3-8	2-3	13-0	—	—	—	—	—	—	—	—	—	37
11-9	10-0	1-0	—	8-3	6-5	4-0	—	5-6	3-4	8-0	—	—	—	—	—	—	—	—	—	37
11-6	—	1-0	—	8-9	5-8	3-0	—	5-4	2-4	8-0	—	3-1	1-8	15-0	—	—	—	—	—	37
20-0	—	—	—	15-0	—	—	—	9-0	—	—	—	5-0	—	—	—	—	—	—	—	28
8-0	5-8	1-0	—	5-8	3-6	3-0	—	—	—	—	—	—	—	—	—	—	—	—	—	37
8-5	6-5	1-0	—	5-8	3-6	4-0	—	3-6	2-0	8-0	—	2-5	1-3	11-0	—	—	—	—	—	37
7-4	—	2-0	—	5-4	3-4	5-0	—	—	—	—	—	—	—	—	—	—	—	—	—	37
11-7	7-0	2-0	—	8-3	4-5	2-0	—	5-6	2-1	5-0	—	—	—	—	—	—	—	—	—	37
17-5	—	—	—	10-0	—	—	—	6-0	—	—	—	3-5	—	—	—	2-5	—	—	—	38
17-1	—	—	76	9-4	—	—	63	4-4	—	—	15	3-2	—	—	19	—	—	—	—	2
11-1	9-6	0-5	—	5-8	4-5	8-0	—	3-6	1-8	10-0	—	2-7	1-3	25-0	—	—	—	—	—	37
10-0	6-7	1-0	—	7-6	4-5	2-0	—	4-9	2-5	7-0	—	—	—	—	—	—	—	—	—	37
10-7	9-7	2-0	—	8-9	6-8	3-0	—	5-6	3-3	10-0	—	—	—	—	—	—	—	—	—	37
12-3	11-6	0-5	—	6-7	4-9	7-0	—	3-8	1-8	10-0	—	—	—	—	—	—	—	—	—	37
16-1	15-1*	0-4	99-3	14-2	14-2*	0-5	64-3	11-2	9-9*	1-1	32-8	5-7	4-2*	6-3	34-2	3-2	3-1*	15-0	9-7	38
14-3	—	0-0	—	8-9	—	8-0	—	4-5	2-2	12-0	—	2-7	1-8	23-0	—	—	—	—	—	37
13-4	9-8	2-0	—	8-0	5-1	8-0	—	5-0	2-8	22-0	—	—	—	—	—	—	—	—	—	37
13-4	10-9	2-0	—	8-0	5-0	7-0	—	5-0	2-5	22-0	—	3-2	1-8	40-0	—	—	—	—	—	37
17-8	—	—	91	10-2	—	—	66	6-3	—	—	63	4-2	—	—	49	—	—	—	—	2
17-8	—	—	96	9-7	—	—	66	5-7	—	—	46	2-4	—	—	33-1	—	—	—	—	3
—	—	—	80	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	34
12-4	—	—	—	12-0	—	—	—	8-0	—	—	—	—	—	—	—	—	—	—	—	35
14-0	—	—	—	9-5	—	—	—	8-0	—	—	—	—	—	—	—	—	—	—	—	35
14-6	—	—	93	9-2	—	—	54	5-1	—	—	58	3-3	—	—	27	—	—	—	—	2
9-0	—	—	73	7-0	—	—	54	5-8	—	—	38	5-0	—	—	30	—	—	—	—	39
8-9	—	—	70	7-0	—	—	50	5-4	—	—	38	4-8	—	—	30	—	—	—	—	39
12-1	—	—	100	6-7	—	—	60	5-5	—	—	60	3-8	—	—	31	—	—	—	—	2
19-1	—	—	109	9-7	—	—	65	6-3	—	—	62	3-8	—	—	32	—	—	—	—	2

W = solution heat treatment
P = precipitation heat treatment
(S) = stabilization treatment

O = annealed
B.W.Q. = boiling water quench
* = values are for 0.1% offset proof stress

TABLE X.—THERMAL PROPERTIES OF SOME PISTON ALLOYS AND HYPEREUTECTIC ALUMINUM-SILICON ALLOYS

Alloy	Condition	Main Constituents (%)						Thermal Expansion Coefficient (/°C. × 10 ⁻⁶)				Thermal Conductivity (cal./sq. cm./cm. ² C./sec.) at 25° C.
		Si	Cu	Mg	Mn	Ni	Fe	20-100	20-200	20-300	20-400	
LM12	s/c M	2.0	10.0	0.25			1.0	22.0		24.0		0.31
LM13	s/c WP	12.0	0.9	1.1		2.5		19.0		21.0		0.28
LM14	s/c WP(8)		4.0	1.5		2.0		22.5		24.5		0.32
LM15	s/c WP	1.3	2.1	1.1		1.3	1.1	22.5		23.0		0.42
D132	c/c P	9.5	3.0	1.0		1.0		20.7	21.2	22.4		0.25
Smith ²⁰	Unrefined s/c	20.0	2.0	1.0	0.5							0.19
	Unrefined s/c P											0.20
	Unrefined s/c WP											0.23
	Unrefined c/c											0.22
	Unrefined c/c P											0.23
	Unrefined c/c WP							16.2 ^a	16.5 ^a	16.8 ^a		0.24
	Refined s/c											0.21
	Refined s/c P											0.22
	Refined s/c WP											0.25
	Refined c/c											0.22
Kissling and Tichy ³⁰	Refined c/c P											0.25
	Refined c/c WP											0.25
		8.1	1.6	0.5	0.5	0.4		21.4	22.1	23.2	23.8	
		9.8	1.6	0.5	0.5	0.4		20.9	22.0	22.9	23.4	
		10.8	1.6	0.5	0.5	0.4		20.5	21.6	22.5	23.2	
		12.3	1.6	0.5	0.5	0.4		20.2	20.9	21.8	22.3	
		16.2	1.6	0.5	0.5	0.4		18.5	19.8	20.9	21.4	
		20.1	1.6	0.5	0.5	0.4		17.8	18.7	19.4	19.6	
		21.1	1.6	0.5	0.5	0.4		17.6	18.4	19.3	19.8	
		25.6	1.6	0.5	0.5	0.4		16.4	16.9	17.5	18.0	
Niral 1761	c/c WP	17.0	1.0	1.0	0.5	3.4			18.5			
	c/c WP	23.5	1.0	1.0		0.9			16.5			
	c/c P	22.0	2.8	0.6		0.9	1.10 ^a	17.2	18.2	19.2	20.5	
	c/c WP							16.8	17.91	18.9	20.1	
Japanese Alloy ²								17.3	18.4	19.4	20.6	
								10.5			12.8	0.112

s/c = sand-cast.
c/c = chill-cast.
M = as-cast.

P = precipitation heat treatment.
W = solution heat treatment.
^a = condition not known.

F. Influence of Composition

There is too little information on the properties of the high-silicon alloys to give any indication of the effects of alloying additions, particularly as the conditions under which high-temperature properties were determined varied from one investigator to another. However, the optimum additions would probably be similar to those in the LM13 type piston alloys of lower silicon content, which have presumably been studied in greater detail (although little has been published on the influence of composition even in these materials).

G. Fatigue Properties

Little work has been published concerning the behaviour of hypereutectic alloys under thermal and mechanical cycling. Kessler and Winterstein⁴⁰ noticed microcracks formed during cooling in the brittle intermetallic constituents of high-silicon alloys containing iron, zinc, copper, magnesium, etc. Löhberg, Schultz and Jung-König⁴¹, although confirming that such cracks form during cooling, have found that after extensive thermal and mechanical cycling the cracks do not propagate through the matrix, but that the initially hard matrix is plastically deformed and softened. Such softening can be remedied by subsequent heat treatment. It has been shown¹⁴ that for Noral 1150-WP and 1152-WP, the fatigue strengths are ± 6 to ± 7 tons/sq. in. at room temperature dropping to $\pm 3\frac{1}{2}$ to $\pm 4\frac{1}{2}$ tons/sq. in. at 300° C. for 10⁶ cycles. Refinement of the primary silicon in 1152-WP with red phosphorus and hexachlor-ethane had no significant effect on the fatigue properties.

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Electric Smelting on Approval

Facilities Provided by Birlefco Pilot Plant at Aldridge



Rabbling the charge to break up the crust which forms on the surface.

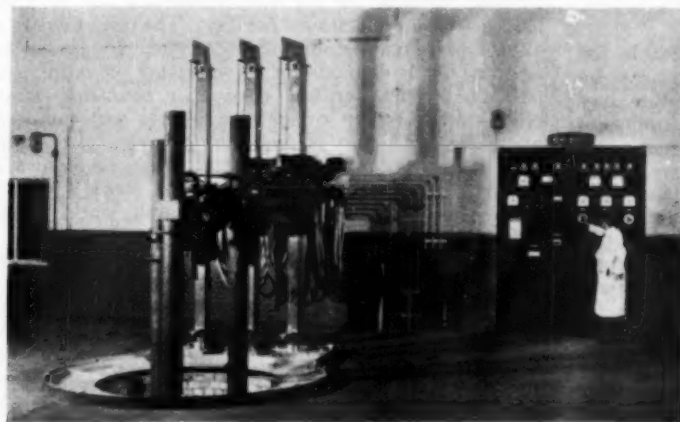
OVER £50,000 has been invested by Birlec-Efco (Melting), Ltd., in a scheme designed to assist rapidly developing countries to exploit their mineral resources. At the Aldridge works, the company has installed a pilot electric smelting furnace, so that firms contemplating the installation of a production-scale electric smelting plant can be assisted in assessing the practicability of their plans without incurring capital expense. It is believed that the scheme will be specially attractive to mining and metallurgical concerns in the Commonwealth, particularly in Africa and India, where the company and its associates have already installed a total of nine electric smelting furnaces with a combined rating of 36,000 kVA.

Particularly where hydro-electric resources are available, the electric smelting process can economically be used for the extraction from their ores of nickel, copper, manganese, iron, ferro-alloys, and other materials. It is intended that firms having an ore or slag which contains metals they wish to extract, and who wish to take advantage of the new facilities, should approach Birlec-Efco with particulars of the problem facing them. After due consideration by the technical staff of the electric smelting department, a programme of tests will

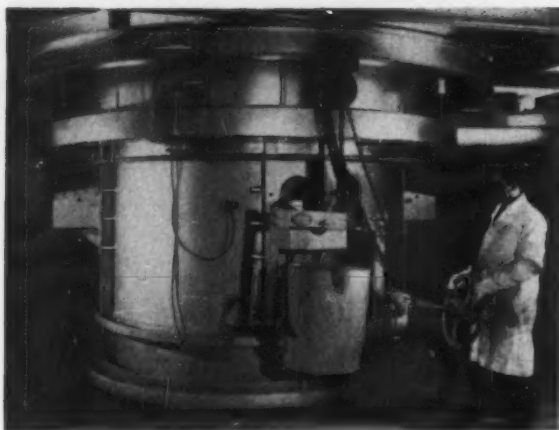
be put forward for discussion, and subsequently carried out on the customer's raw materials at a fee agreed in advance, the finished products and the balance of the raw materials being returned to the customer. The object of the tests is to assess the amenity to electro-thermal reduction of the customer's raw materials; to determine the most suitable smelting technique; and to establish the nature of the resultant products. The plant is of such a size that valuable information is obtained on such important factors as power and electrode consumption, operating voltage, percentage recovery and other relevant data. This information can be scaled up so that a fairly accurate appraisal can be made of what can be expected on a large scale plant. At the conclusion of the test programme, Birlefco will provide a full report, giving recommendations on smelting practice, electrical rating and size of installation required for a given output.

Building and Plant

The building specially designed to house the Birlefco pilot smelting furnace has a total floor area of 5,700 sq. ft., which is served by a 5 ton overhead travelling crane with a maximum height of lift of 26 ft. The substation, which is integral with the main building, is in an area



Operating platform and control panel.



Preparing to tap the furnace: ladles are suspended from an overhead mono-rail system which forms a loop round the furnace, enabling the ladles to be transferred easily from the taphole to the moulds for casting.

adjoining the furnace and platform. Ample provision has been made for storage of refractories, electrodes and raw materials, and equipment for crushing, ladle heating and casting has been installed.

The Pilot Smelting Furnace

The furnace, with a shell of 8 ft. internal diameter, is situated at one end of the building, and is surrounded by a charging platform at a height of 9 ft. from the main floor level. The furnace controls are suitably housed in a panel adjacent to the furnace operating platform. With a nominal rating of 350 kVA, the furnace is designed to be as versatile as possible, and a wide range of voltage tapplings have been provided enabling, as far as practicable, the whole range of electric smelting applications to be covered.

To determine the effect of shell movement in breaking up crusts, etc., which may form in some smelting operations, the shell can be rotated or oscillated in either direction at varying speeds. Three tapholes are provided, the levels of which can be altered for slag and metal, and these are served by a mono-rail beneath the platform, forming a loop surrounding the shell. The hearth and lower side walls are of carbon and the upper side walls of firebrick, and several thermocouples are built into the refractory lining to monitor the temperature of the hearth and sidewalls at different points.

The furnace is equipped with holders suitable for 8 in. diameter electrodes, but smaller holders can be fitted if necessary. Amorphous carbon or graphite may be used for the electrodes, according to the requirements of the tests. The former is cheaper but it cannot carry such heavy currents as graphite for the same size of electrode. The electrode clamps are arranged for remote control by pneumatically operated cylinders.

The furnace is so designed that it can be operated as an open-top unit or, if desired, a roof can be superimposed. Working conditions on the furnace platform are good, due to the excellence of the arrangements for removing gas and fume.

Substation Equipment

The substation, which is integral with the main building, houses the high voltage contactor, furnace transfor-

mer, 0.7 kW. Amplidyne electrode controller, and low tension distribution board.

Transformer.—Nominally rated at 350 kVA, the A.E.I. three phase transformer has an ancillary cooler enabling higher outputs to be attained for special smelting applications. Full output is available on all secondary tapplings. The transformer is arranged so that its secondary windings can be connected in series or parallel. With the series connection a voltage range of 250/130 V. in 20 V. steps is available, and with the parallel connection a range of 125/65 V. can be obtained in 10 V. steps. The transformer has a nominal reactance of 5% at maximum secondary voltage and current.

For special work, a tapped reactor is available to provide arc stability. This reactor provides a number of equal steps which can be preselected with any value of voltage by means of the common motorised tap-change switch. In addition to the motorised tapping switch for normal operation, emergency hand tap-change control is provided, suitably interlocked with the circuit breaker to ensure off-circuit operation.

Power Supply.—The control of the power supply to the furnace is provided by a high voltage contactor, backed up by an oil circuit breaker which gives protection against short circuit and excessive overload. Under-voltage protection is provided in the contactor.

Electric Smelting and its Applications

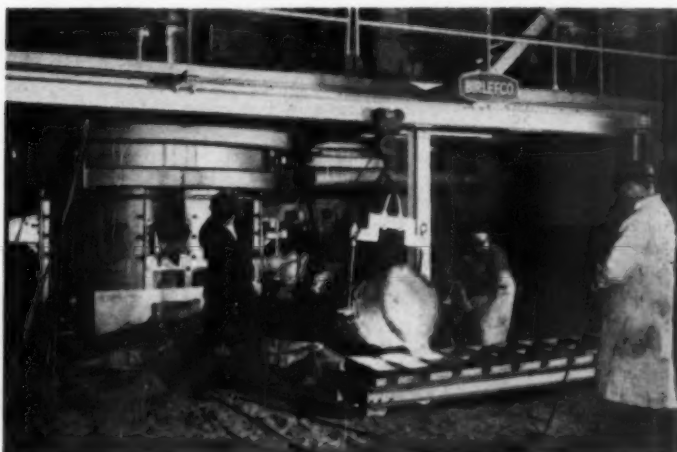
The most economical method of producing the very high temperatures required for the reduction of many ores is by the use of electro-thermal smelting. This method is also used where contamination of the product by ash in the conventional solid fuel process is undesirable. For certain metals and alloys it is accepted as the only economic process, and the method is also gaining acceptance in the production of what are generally known as the "rarer metals" and other alloys.

Though accepted for over fifty years as a feasible method for extracting metals from their ores, only in recent years has electric smelting been carried out on a significant scale. The main factor contributing to this development is the relative cheapening of the unit cost of electricity when compared with other fuels. With the continuing development of the electrical generating industry there is likely to be a greatly increased use of the electro-thermal smelting process by industry.

Where economic conditions are favourable, electric smelting furnaces for pig iron production are installed in capacities up to 220 tons per day. The blast furnace is still the principal metallurgical equipment for producing pig iron, but it depends for its operation on supplies of high grade metallurgical coke. In countries where hydro-electric power is plentiful, and its cost compares favourably with that of metallurgical coke, electrically smelted pig iron can be produced more economically than the blast furnace product; and some 3,000,000 tons are produced annually throughout the world by this method.

Of special importance in the metallurgical field is the production of ferro-alloys for the steel industry by electric smelting. The materials in this group include ferro-silicon, ferro-chromium, ferro-manganese, ferro-tungsten, etc. Ferro-silicon and ferro-manganese are essential for the deoxidation of steel, and they and other ferro-alloys are also used as alloying agents in the production of special steels.

Molten metal smelted from its ore is here being poured from a ladle into moulds.



Silicon metal with a purity exceeding 96% can advantageously be extracted by electrothermal methods. The main metallurgical use of silicon metal is as an alloying element for non-ferrous metals, in particular copper and aluminium: it is also used as a reducing agent in the production of certain ferro-alloys. In recent years a new range of chemical compounds known as silicones has been developed on a large scale and silicon metal can be used as a starting point for these compounds.

Under certain conditions, electric smelting can also be used advantageously in processes concerned with the extraction of many non-ferrous metals including copper, nickel, tin and zinc.

Whilst electric smelting is of primary concern to the metalliferous mining industries, the process is indirectly of great importance to the chemical, plastics and general engineering industries. Prior to the last war Great Britain relied upon the importation of calcium carbide, but there is now a well established carbide producing industry in the country. The reaction of this material with water produces acetylene gas, which is widely used in the engineering industry in conjunction with oxygen for cutting and welding.

Perhaps less well-known is the use of acetylene by the chemical industry as a raw material for the synthesis of P.V.C. plastics, trichlorethylene solvents, acetone and acetaldehyde, and synthetic rubbers. Of these two principal uses in the United Kingdom, some 40% goes into the engineering industry, whilst the balance is used in the chemical industry.

Carbide can also be reacted with nitrogen to form calcium cyanamide, the principal use of which is as a fertiliser. Cyanamide itself, with carbon dioxide, produces dicyandiamide, which is the basis for plastics of the melamine group.

Another application of the electric smelting furnace, of importance to the chemical industry, is the production of phosphorus in its elemental state from phosphate rock. The phosphorus is subsequently used in the production of the various phosphorus compounds required by industry, especially for fertilisers and detergents.

Although it is not suggested for one moment that the new development at Aldridge is anything other than a commercial venture, it could play an important part in the economic growth of former colonies now achieving

independence, and in so doing strengthen the bonds uniting the members of the British Commonwealth.

Enamelling Aluminium

(continued from page 64)

Two companies are offering hollow-ware vitreous enamelled on the outside, and there is no doubt that the domestic field, especially appliances, offers a further potential market. In particular, once a satisfactory technique has been developed for castings, a number of new markets suggest themselves. With the present continual search for better materials, better frits and improved processing conditions, there should be a steady growth in demand for this still relatively new product.

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Confidence in Plating

REFERENCE was made in a recent issue to the new British Standard for chromium plating and to the Mond labelling scheme for indicating the quality of plating on a particular article. As part of the campaign to increase confidence in chromium plating, an exhibition organised by The Mond Nickel Co., Ltd., was held recently in the Engineering Centre, Birmingham, where visitors could see items covering the electroplating process; the new British Standard; methods of measuring the thickness of plating; the Mond labelling scheme, and how it can be used to identify the quality of chromium plate; and research and technical progress in plating. Associated with the exhibition was a series of discussions covering design for plating, the application of the new British Standard, and the Mond labelling scheme.

News in Brief

ROTO-FINISH, LTD., specialists in finishing processes for the metal and plastic industries, have acquired a substantial interest in **N. V. Roto-Finish Maatschappij**, Delft, Holland, a company which is engaged in similar business in the Benelux countries. An agreement has also been reached whereby the sales programmes and the service organisations of the two companies will be integrated.

AEI-BIRLEC, LTD. is building two continuous pusher furnaces for annealing whiteheart and blackheart malleable iron castings, respectively. The former, which will be the first continuous furnace in the country to be used for the gaseous annealing of whiteheart malleable castings, is to be rated at 250 kW. to give an output of 100 tons of castings per month. The second unit, for annealing 50 tons/week of ferritic blackheart malleable castings, will be rated at 390 kW.

BRITISH OXYGEN GASES, LTD., who have undertaken development work in the United Kingdom in the tungsten arc cutting process, are now marketing the equipment in arrangement with **Union Carbide, Ltd.** The process was originally developed for form-cutting readily oxidised metals, such as aluminium, stainless steel, titanium and copper.

CARBLOX, LTD., a member of the Marshall Refractories group of companies have received an order to supply carbon refractories to Messrs. Ashmore, Benson, Pease and Company for the two 30-ft. diameter blast furnaces they will be installing at the proposed new **Richard Thomas and Baldwins' steelworks** at Newport (Mon.).

NEW METALS AND CHEMICALS, LTD., of Chancery House, Chancery Lane, London, W.C.2, have been appointed sole U.K. distributors of hyperpure silicon produced by **Trancoa Chemical Corporation**, one of the leading manufacturers of semiconductor grade polycrystalline and single crystal material.

HOOVER, LTD. have acquired the lease from **Wales and Monmouthshire Industrial Estates** (acting for the Board of Trade) of a 68,000 sq. ft. factory at **Merthyr Tydfil** on the opposite side of the road to the main factory building of **Hoover (Washing Machines), Ltd.** This will bring the total area occupied in South Wales by the **Hoover Washing Machine** enterprises up to some 800,000 sq. ft.

THOMAS MARSHALL AND CO. (LOXLEY), LTD., are now producing refractories for blast furnace plant in the Argentine against an order obtained last year amounting to approximately £12,000, for delivery in March.

In connection with contracts placed for the construction of a new oil refinery in Brazil for **Petrobras Duque de Caxias**, **Birlec** is to supply through **Brefcon, Ltd.**, two adsorption dryers and an inert gas generator of 15,000 c.f.h. capacity. The dryers are to be used for drying 50 U.S. gallons per minute and 100 U.S. gallons per minute, respectively, of liquefied petroleum gas.

The Bristol branch of **Wolf Electric Tools, Ltd.**, has moved into new and larger premises at 1-3 Dean Street, Bristol, 2. The original Wolf service branch at Cheltenham Road has been vacated and all enquiries should be made to the new Dean Street address (telephone: Bristol 22288).

WILD-BARFIELD ELECTRIC FURNACES, LTD. have recently received orders from **The Rover Co., Ltd.**, for gas carburising furnaces having useful work space dimensions of 16 in. diameter \times 32 in. deep, and from **Leyland Motors, Ltd.**, for equipment 24 in. diameter \times 46 in. deep. All these furnaces will employ **Carbodrip** as the gas carburising medium in the drip feed method.

ELECTROPOL PROCESSING, LTD., Trading Estate, Farnham, Surrey, have found it necessary to increase the number of telephone lines serving the works and offices. This has involved a change in number to Farnham 3355.

THE Electric Resistance Furnace Co., Ltd. has received an order from the **United Kingdom Atomic Energy Authority** for furnaces for the heat treatment of nuclear fuel elements. The order, valued at over £15,000, covers the supply of six **Efco-Lindberg** furnaces fitted with external forced-convection heating units. The company has already supplied twelve furnaces of the same type for the same process.

ELECTRO METHODS, LTD. have announced the removal of their **Electrical Connector Division** to new premises at **Hitchen Street, Biggleswade, Beds.** (telephone: Biggleswade 2086 (3 lines)).

WOODALL-DUCKHAM CONSTRUCTION CO., LTD., has received an order from the **Sierra Leone Development Co., Ltd.**, to build an ore preparation plant valued at more than £300,000. The plant, which will be built at **Marampa**, will be capable of dealing with 110 tons of crude iron ore per hour. Constructional work will commence in September of this year and will be completed by June 1961.

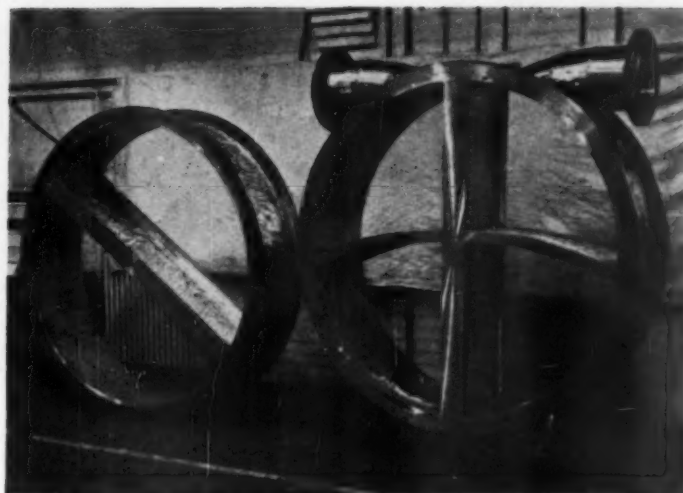
CHINA has placed another order to the value of £8,000 for six gas-liquid chromatographic analysis equipments manufactured by **Griffin and George, Ltd.** This is the second large order to be received from China in twelve months, making the number of these instruments now in use in China nine.

BAKER PERKINS announce that their **Bedewell Division**, **Hebburn-on-Tyne**, have appointed a foundry machinery advisor. He is **Mr. F. Wilson**, who joins the company's foundry machinery department in a part-time capacity. **BURTON, GRIFFITHS & CO., LTD.**, who have held the representation for the **Gisholt Machine Company**, **Madison, U.S.A.**, for a period of sixty-seven years, covering the range of ram-type turret lathes, combination turret lathes, hydraulic production lathes, **Simplimatic** automatic lathes and **Dynetric** balancing machines, announce an important extension of their activities concerning **Gisholt** machines and equipment. As from 1st March, 1960, they are sole concessionaires in the United Kingdom for **Gisholt** superfinishing machines and **Fastermatic** automatic turret lathes. **Burton, Griffiths & Co., Ltd.**, have also been appointed sole agents in the United Kingdom for **Gisholt Machine Company (G.B.)**, Ltd., for the range of machines to be manufactured for them by **Lang-Gisholt Machine Co., Ltd.**, at **Johnston, Scotland**.

The **Russian Trade Delegation** has placed an order worth £16,000 for thirteen gas-liquid chromatographic analysis equipments with **Griffin & George, Ltd.** The order is the result of demonstrations given to the delegation's scientific representatives at the laboratory at **Alperton** and at the **Symposium on Micro Chemistry** in **Birmingham** in 1959. This is the second order from the **U.S.S.R.** during the last twelve months: the first was for six instruments.

Aluminium Bronze Fabrications

Welding Problems Overcome



The fabricated return and water boxes.

TO those brought up to regard brass primarily as an alloy of copper and zinc and bronze as an alloy of copper and tin, the loose terminology prevailing in the copper alloy field is somewhat confusing. For example, the name "manganese bronze" is given to a material which is not a bronze at all, but a high tensile brass containing manganese in addition to the copper and zinc. Similarly, aluminium bronze contains no tin, but is basically an alloy of copper and aluminium, just as beryllium bronze is an alloy of copper and beryllium.

Aluminium Bronze Alloys

"Aluminium bronze" is frequently referred to as if it were a specific material, whereas in fact the term—like "brass"—embraces a whole series of alloys, with Brinell hardness values ranging from 90 to 425. The softest alloys have an aluminium content of about 5%, with an ultimate tensile strength of 25 tons./sq. in. and an elongation of 70%. As the aluminium content increases up to the practical limit of 8% for a single-phase solid solution alloy, the strength progressively increases. The most popular alloy for fabrication has an aluminium content of 7.5% and an iron content of 2.5%: it has an ultimate tensile strength of 35 tons./sq. in., and an elongation of 35%. When the aluminium content exceeds 8%, a duplex alloy is formed, which is harder and stiffer than the single-phase alloy. Complex alloys are formed when other elements—notably iron and nickel—are added to the duplex alloys, resulting in the formation of a new nickel-iron-rich phase. Forgings for engineering purposes in an alloy containing 10% aluminium and 5% each of nickel and iron may have an ultimate tensile strength of 50 tons./sq. in. and an elongation of 15%. The hardest alloys contain 14% aluminium and are sufficiently resistant to wear to be used as press tools for the deep drawing of stainless steel, Nimonic, etc. These tools do not fret or scuff with the sheet being drawn, and completely scratch-free pressings are produced.

The aluminium bronzes are today well established as engineering alloys with extremely useful properties,

being stronger than many steels at normal temperatures. The single-phase alloys show attractive low temperature properties, with impact values of 60 ft. lb. maintained as low as -200°C . At the other end of the scale, the complex alloys retain useful physical properties up to 400°C , with complete absence of scaling. To these properties must be added the important one of corrosion resistance, which is especially high in relation to attack by sea water, chlorides, and dilute sulphuric and hydrochloric acids. This resistance, like the resistance to scaling, is conferred by the tenacious film of aluminium oxide formed on the surface: this film is continuous and self-healing under most conditions.

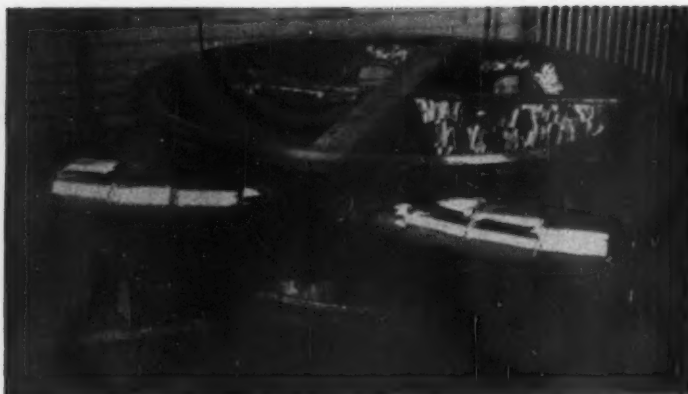
Existing applications in which resistance to corrosion is the prime consideration include pressure vessels, evaporators, heat exchangers and condenser tubes and tube plates. In the oil industry heat exchanger parts are subjected to the attack of sea water on one side and oil distillates, frequently acid-bearing, on the other. Where higher strength together with resistance to corrosion is required, as in marine engineering, complex aluminium bronzes are favoured for propellers, propeller shafts and pump parts, "A" brackets, stern tube bearings, and deck fittings.

Welded Fabrications

The aluminium bronzes are used in both the wrought and cast forms. In some instances, however—whether because of size, intricate shape, or thinness of section—it is necessary to resort to fabrication methods of construction, and some interesting examples of this were provided recently with the completion, by W. P. Butterfield, Ltd., of the first of four pairs of water and return boxes for four large tubular heat exchangers for an oil refinery. The boxes are 6 ft. 6 in. in diameter, with main cylinders in $\frac{5}{8}$ in. plate and fabricated inlet and outlet branches in $\frac{3}{4}$ in. plate. Each pair weighs about 2 tons.

Co-operative Effort

The order for these fabrications is the outcome of successful collaboration between W. P. Butterfield, Ltd.,



A closer view of the water box.

of Shipley, and N. C. Ashton, Ltd., of Huddersfield. The latter company specialises in the production of aluminium bronzes, and has been successful in maintaining close tolerances on the aluminium content of the various grades, without which variations in properties are inevitable. Believing strongly in the potentialities of these alloys in the construction of process plant, N. C. Ashton developed hot rolled sheets down to 24 s.w.g. and large forgings and plates of 2-4 tons in weight for heat exchanger tube plates. After early attempts at welding aluminium bronze had been attended by only indifferent results, N. C. Ashton contacted Butterfields, makers of tanks for bulk transport of liquids and of industrial processing plant. The nature of their work has resulted in the Shipley company having a wide experience of the fabrication and welding of difficult materials. This formed a sound basis for their determination to overcome the initial difficulties and establish themselves as leaders in the field of aluminium bronze welding.

The weldability of the aluminium bronzes can be favourably compared with that of competitive materials, once the problems arising are appreciated. For instance, the oxide film which is so useful in maintaining corrosion resistance is not so welcome to the welder. By virtue of the relatively high thermal conductivity of the material and the ease with which refractory oxides are formed, a highly concentrated heat source and a fully shielded weld pool are essential requirements of the welding process. The Mig (metal inert gas), Tig (tungsten inert gas) and metal arc processes are the most suitable, and in the case of the water and return boxes the inert gas shielded arc processes were used throughout, chiefly the metal inert gas process in which a consumable electrode is used.

Complex Weld Deposits

The more ductile single-phase alloys are preferred for fabrication work where forming is involved—particularly cold forming—and in the present instance aluminium bronze to A.S.T.M. B169 alloy D, containing approximately 7.5% aluminium and 2.5% iron, was used. The weld metal composition is an important factor in the successful joining of this material, since single-phase weld metals are susceptible to hot cracking. This is rather unfortunate as the single-phase alloys, by reason of their excellent ductility, are readily drawn into wire; whereas complex alloy wires are more difficult to pro-

duce, due to their higher strength and lower cold ductility.

Deposits from the complex alloy wires are, however, reasonably free of cracking, and extensive development work by N. C. Ashton, Ltd., resulted in the production of Nartrode E, a homogeneous complex alloy wire containing nickel and iron and conforming to A.S.T.M. B171 alloy E. Typical mechanical properties of the weld metal deposited from this wire are an ultimate tensile strength of 43 tons/sq. in. and an elongation of 29%.

The preparation of plates and sections for fabrications is done by shearing, friction band sawing and machining, the choice being governed by the thickness. Oxy-acetylene flame cutting is not possible, but considerable success is being achieved with the tungsten arc cutting process. In the early attempts at welding aluminium bronze, difficulties were experienced in meeting the necessary radiographic standards, but as the development work progressed these difficulties were overcome. One of the factors of importance in producing high quality welds to radiographic standards is the thorough cleanliness of the joint faces and filler wire material. Pre-heating is necessary, particularly at the start of welds.

Many fabrications involve the welding of aluminium bronze to other materials, and sufficient evidence is available to show that sound weld joints can be made in these circumstances. The layering of mild steel flanges with an aluminium bronze surface was an essential feature of the fabrications illustrated here, and the first stage in the welding of the flange to the body was a similar "buttering" or surface cladding operation on the mild steel.

Aluminium bronzes in the form of forgings and castings are already established in chemical, marine, nuclear energy and petroleum engineering, and now that welded fabrications in wider variety are commercially available, the attractive properties of this series of alloys can be utilised more extensively in these and other industries. The sales staffs of W. P. Butterfield, Ltd., and N. C. Ashton, Ltd., have joined forces in putting aluminium bronze welded fabrications on the market and further contracts have already been accepted.

THE Turbine Generator Division of Associated Electrical Industries, Ltd., has received an order from Atomic Energy of Canada, Ltd., for a 220-MW. steam turbine-generator for the nuclear power project at Douglas Point on the eastern shore of Lake Huron. The value of the order is about £2 million.

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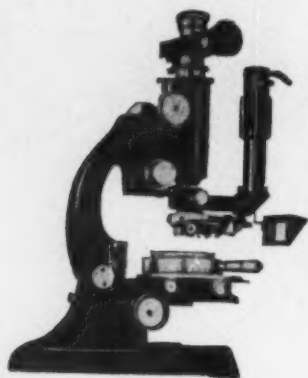


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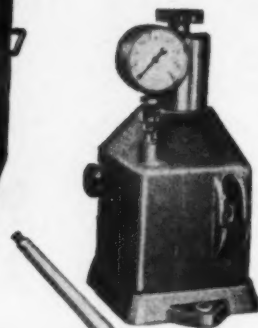
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NEWS AND ANNOUNCEMENTS

Institute of Metals Spring Meeting

THE Institute of Metals Spring Meeting, to be held in London from Tuesday, 29th March, to Thursday, 31st March, will open with the Annual General Meeting at Church House, Great Smith Street, London, S.W.1. The business part of the meeting will commence at 10 a.m. and during its course the new president, Sir Ronald Prain, O.B.E., will be installed. At about 11 a.m., Sir Ronald will deliver his presidential address on "Mineral Resources and Metal Reserves," and afterwards will present the Institute medals to their recipients: Professor R. F. Mehl (the Institute of Metals Platinum Medal); Professor N. J. Petch (the Rosenhain Medal); and Dr. M. Cook and Mr. E. Swainson (the W. H. A. Robertson Medal and Premium).

An attractive programme of technical sessions has been arranged, and this opens at Church House on the Tuesday afternoon, when papers on precipitation effects in liquid aluminium alloys and the embrittlement of aluminium-magnesium alloys by sodium will be discussed. The morning session on Wednesday, 30th March, has been organised by the Nuclear Energy Committee, and will be devoted to a discussion of the volume increase in fissile materials on neutron irradiation. In the afternoon there will be an educational session on new aspects of the electron theory of metals which is referred to elsewhere in our columns. A whole day discussion on rolling hard materials in thin gauges has been arranged by the Metallurgical Engineering Committee for 31st March, and as alternatives there will be a discussion on vacancies, ageing and precipitation in the morning, and on resistance to deformation of aluminium in the afternoon.

Functions arranged for the evenings include the May Lecture, a conversazione and exhibition, and the annual dinner. This year's May Lecturer is Professor P. M. S. Blackett, F.R.S., whose subject will be "The Magnetism of Rocks and Continental Drift." The time and location are 6.30 p.m. on Tuesday, 29th March, and Church House, respectively. Members and guests will be received by the president from 7.30 to 8 p.m. on Wednesday, 30th March, on the occasion of the conversazione and exhibition at the Institute's headquarters at 17 Belgrave Square, London, S.W.1. To wind up the Spring Meeting, the annual dinner will be held at Grosvenor House, Park Lane, on Thursday, 31st March, when the Institute will be honoured by having as guest the Prime Minister, the Rt. Hon. Harold Macmillan, P.C., M.P.

Nickel Alloys in Industry Exhibition

THE outstanding success of the previous exhibition held in London has prompted Henry Wiggin & Co., Ltd., to stage a similar exhibition at Park Lane House, 45, Park Lane, W.1, from 21st-25th March, 1960: it will be open daily from 10 a.m. to 8 p.m., closing at 5 p.m. on Friday 25th. The aim of the exhibition is to help engineers and designers to make the best use of the specialised alloys made by the company. These alloys fall mainly into four groups, corrosion-resisting alloys, heat-resisting alloys, electrical resistance alloys, and materials with special properties. The display will include a large selection of

actual components, sub-assemblies, and finished parts in which Wiggin materials play vital rôles.

During the exhibition a series of lectures will be given on subjects including fabricating the high-nickel alloys, and a series on the uses of high-nickel and nickel-base alloys in the production of nuclear power, in heat-resisting applications, in the electrical and electronic industries, and in chemical engineering. Throughout the exhibition the Company's technical staff will be available to answer visitors' queries and publications covering the complete range of Wiggin products will be available. The exhibition will be augmented by a continuous showing of films on applications and fabrication of Wiggin products.

Midlands Instrument Exhibition

A. M. LOCK AND CO., LTD., announce that many new devices will be exhibited among the four hundred instruments on show at their Fourth Annual Exhibition of Electronic, Chemical and Nuclear Instrumentation Equipment, which is to be held in the Bennett Hall, Central Y.M.C.A., Snow Hill, Birmingham, 4. The hours of opening are 2.30 p.m. to 7 p.m. on Tuesday, 22nd March, 1960, and then daily from 10 a.m. to 7 p.m. until Friday, 25th March, 1960.

The display will include equipment from the following firms: Cossor Instruments, Ltd.; Elcontrol, Ltd.; Elop Moisture Meters; Evans Electro Selenium, Ltd.; Dr. W. Ingold (Zurich); A. M. Lock and Co., Ltd.; W. G. Pye and Co., Ltd.; Stonebridge Electrical Co., Ltd.; Southern Instruments, Ltd.; and Telequipment, Ltd.

During the course of the exhibition, the following lectures will be given:

- "The use of electronics in mechanical engineering" by R. T. LANCASTER (Southern Instruments, Ltd.).
- "Flame detection systems for furnace safeguard applications" by F. G. FISHER (Elcontrol, Ltd.).
- "Recent developments in gas chromatography" by R. S. EVANS (W. G. Pye and Co., Ltd.).
- "pH measurement and control" by A. M. LOCK (A. M. Lock and Co., Ltd.).
- "Automatically controlled continuous detoxication plants for trade wastes containing cyanide and chromate" by K. MELLOR (A. M. Lock and Co., Ltd.).

Further details and tickets of admission to the lectures may be obtained from A. M. Lock and Co., Ltd., Newborough House, Newborough Road, Shirley, Solihull, Warwick.

Spring Welding Meeting

THE Spring Meeting of the Institute of Welding will be held at Droitwich from 9th to 11th May, 1960, and will be devoted to the novel welding processes and metal spraying. The provisional programme includes an opening reception at the Worcestershire Brine Baths Hotel in the early evening of Monday, 9th May, two morning sessions, on Tuesday and Wednesday, for the discussion of technical papers, a choice of works visits on the Tuesday afternoon, and a concluding dinner on the Wednesday evening. It is hoped to arrange demonstrations on the Tuesday and Wednesday.

The conference centre will be the Winter Gardens,

Droitwich, and most of the supply manufacturers will be taking part in a small exhibition of photographs, literature, etc. Five papers on different aspects of metal spraying have already been prepared, and it is intended to devote the whole of one technical session to these.

Direct Rolling in Powder Metallurgy

THE Powder Metallurgy Joint Group of the Iron and Steel Institute and the Institute of Metals will hold an informal discussion on "Direct Rolling Processes in Powder Metallurgy" in the Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1, on Tuesday, April 12th, 1960 (not on April 11th and 12th as had been previously announced). At the first session (10.30 a.m. to 12.30 p.m.) the following papers will be presented for discussion:

- (1) MARSHALL: "Some Mechanical Requirements of Plant for the Roll Compacting Process."
- (2) DIEBEL, THORNBURG and EMLEY: "Continuous Compaction by Cyclic Pressing."
- (3) BEDDOW and FORRESTER: "Continuous Sintering of Copper-Lead to Steel."

The discussion will be resumed at 2.30 p.m. when the following four papers will be discussed.

- (4) EVANS and SMITH: "The Compaction of Metal Powders by Rolling. I—The Properties of Strip Rolled from Copper Powders."
- (5) EVANS and SMITH: "The Compaction of Metal Powders by Rolling. II—An Examination of the Compaction Process."
- (6) WORN and PERKS: "Production of Pure Nickel Strip by the Direct-Rolling Process."
- (7) HUNT and EBORALL: "The Rolling of Copper Strip from Hydrogen-Reduced and other Powders."

Papers Nos. 4, 5 and 6 were published in *Powder Metallurgy*, 1958, No. 3 and the remainder will appear in 1959, No. 5, due for issue in March. The afternoon session will terminate at 5.0 p.m., and will be followed at approximately 5.30 p.m. by a cocktail party in the Bishop Partridge Hall at Church House (Tickets price 12s. 6d. each). Visitors will be welcome; tickets of admission to the meeting are not required.

Educational Session on the Electron Theory of Metals

ARRANGED by the Metal Physics Committee of the Institute of Metals, an educational session on "New Aspects of the Electron Theory of Metals" will be held in the Hoare Memorial Hall, Church House, Great Smith Street, London, S.W.1., on Wednesday, 30th March, at 2.30 p.m. Visitors will be welcome; tickets are not required. The following three brief lectures will be given, each of which will be followed by questions: Dr. W. M. Lomer, a general survey, Dr. V. Heine, on recent experimental work; and Dr. J. Friedel, on the electron structure of alloys.

Metallurgists are familiar with the basic ideas of the electron theory of metals, as laid down in the period 1920-1940, and with the application of these ideas to the understanding of the structures and compositions of certain alloy phases, e.g. electron-compounds. The extension of this work to alloys of transitional and other more complex metals has proved less fruitful, however, and there are now doubts about whether one should continue trying to understand this wider range of alloys by more intensely applying the same ideas, or whether

the present difficulties indicate some basic weakness in that approach, in which case an entirely new approach may be needed.

The dilemma has been sharpened by the intense questioning of the fundamental theory and by the new points of view that have appeared in recent years. The difference between metals and insulators is now thought to depend on the ionisability of atoms rather than on the filling of Brillouin zones. Experiments have proved that the Fermi surface, which is not supposed in the old theory to touch the Brillouin zone boundary until the limit of the *alpha* phase is reached in copper alloys, in fact already touches it in pure copper; this appears to strike at the whole basis of the electron theory of alloys. New ideas have emerged in recent years about the state of valence electrons round alloy atoms in metals; about the behaviour of the free electrons as an "oscillating plasma"; about the electronic structure of transition metals; and about the nature of valence bonds in solids.

It is thus a very timely moment for metallurgists to ask what are the changes now taking place in the basic theory, what new features are likely to emerge, how much is likely to remain of the old theory, and in what directions should one attempt to go forward now to gain a better understanding of alloying behaviour. These are the questions which it is hoped will be answered at this meeting.

Aluminium Contract Cancelled

ACCORDING to an announcement by Aluminium, Ltd., of Canada and Aluminum Co. of America (Alcoa), the two producers have reached an agreement whereby approximately 59,000 tons of aluminium under contract for delivery over the two years 1960 and 1961 by the Canadian producer to the U.S. company will be cancelled against payment by Alcoa in 1960 of a fee of approximately \$9 million.

The cancelled quantity represents about 10% of the total quantity of 600,000 tons which was originally contracted for by Alcoa in 1953. Alcoa is completing new smelter facilities in the U.S. whose output will augment that company's available supplies. Aluminium, Ltd., states that in view of its current sales prospects the company's recently announced production schedule of 675,000 tons of aluminium from its Canadian smelters in 1960 remains unchanged.

S.C.O.W. Development Plan

THE IRON AND STEEL BOARD has approved the fourth development plan of the Steel Company of Wales in a modified form. The object of the plan is to increase the steelmaking capacity of the Abbey Works from 3.0 to 3.6 million ingot tons per annum and the company's production of sheet and tinplate by 400,000 tons per annum. Approval has been given on the basis that arrangements will be made to enable large ore-carrying ships to be used.

No further additions to coke ovens, blast furnaces, or steel melting shops are envisaged, but certain modifications are to be carried out in the light of experience already obtained to give increased efficiency and performance. A continuous casting plant will be installed for the production of steel slabs; this is the first time such a process, which has considerable advantages from the point of view of production costs, has been introduced on a large scale in the U.K.

It was originally proposed to have a 48 in. wide hot strip mill alongside the 80 in. hot strip mill, with a view to providing greater flexibility as well as a measure of reserve capacity. At the request of the Iron and Steel Board this move has been excluded from the plan, and arrangements have been made whereby Richard Thomas & Baldwins will roll slabs for Abbey Works in the hot mill now under construction at the new Spencer Works near Newport, the hot rolled coils being returned to the Steel Company of Wales for conversion into sheet and tinplate. The agreement between the two companies will operate for a minimum of five years.

Personal News

As plans for the merging of the resources of Reynolds T.I. Aluminium Ltd. with The British Aluminium Co., Ltd., are now well advanced, the following changes of appointments have been announced. These changes took effect from February 1st and, pending completion of the plans, the new appointments will cover the operations of both companies. MR. G. LACEY, commercial director, British Aluminium, is to be executive director (forward planning) with special responsibility for studying and co-ordinating long-term planning for the development of production, fabrication and research interests in the U.K. and overseas; MR. G. A. ANDERSON, director and general sales manager, British Aluminium, is to be director of products and development with responsibility for the products, development and technical service organisations; MR. B. JAMES, chief executive (sales), Reynolds T.I. Aluminium, is to be director of sales with responsibility for the sales, publicity and marketing organisations; MR. J. SALTER, director and general production manager, British Aluminium, is to be director of engineering with responsibility for civil, mechanical and electrical engineering and building work at U.K. and overseas establishments; MR. P. R. McGEHEE, chief executive (production), Reynolds T.I. Aluminium, is to be director of production (manufactured products) with responsibility for operations at the company's mills and associated establishments; and MR. W. B. C. PERRYCOSTE, director and general production manager, British Aluminium, is to be director of production (primary products) with responsibility for mining, alumina production and aluminium smelting operations at U.K. and overseas establishments.

DR. H. H. BURTON, C.B.E., has retired from the board of directors of English Steel Corporation, Ltd., as from January 31st, but he will continue as research consultant to the group until the end of the year. Dr. Burton joined the staff of the research department of Cammell Laird and Co., Ltd., in 1907 and later became assistant superintendent of that department. After the formation of English Steel Corporation, Ltd., in 1929, he was appointed senior assistant to the late Mr. J. H. S. Dickenson, whom he succeeded as chief metallurgist of the company in 1934, and was appointed a special director in 1938. Dr. Burton is a past president of the Iron and Steel Institute, chairman of a number of B.I.S.R.A. research committees, and a member of several technical committees concerned with metallurgical aspects of engineering materials. Dr. Burton is succeeded as chief metallurgist by MR. T. R. MIDDLETON, who has also been appointed a special director. Mr. Middleton

joined Cammell Laird and Co., Ltd., Sheffield, in 1922, and after periods in the laboratory and various production departments—particularly melting shops—he was transferred in 1935 to the research department and has since acted as a principal in all aspects of the Corporation's metallurgical work.

THE appointment of MR. E. E. HEWETT as sales engineer has been announced by Nash and Thompson, Ltd., of Hook Rise, Tolworth, Surbiton, Surrey. Mr. Hewett was previously a specialist in ultrasonic flaw detection techniques at Cossor Instruments, Ltd., and is now responsible for the Nash and Thompson sales of the KOVO polarographs and electron microscope throughout the United Kingdom, plus metallurgical, electronic test, process control, medical and survey instruments in the counties of Essex, Middlesex, Herts., Suffolk, Norfolk, Cambridge, Hunts., Beds., Bucks., Oxford, Gloucester, Shropshire and all Wales.

MR. G. P. THOMPSON, until recently manager of the transformer factory at Rugby works, has been appointed manager—manufacturing—A.E.I. (Rugby), Ltd. Mr. Thompson joined B.T.H. as a student apprentice in 1930, and at the end of his term was appointed to the staff of the transformer engineering department. In 1943, he was appointed technical assistant, and in 1950, chief assistant to the superintendent of the transformer factory, becoming manager of that factory in October, 1953. As manager of the transformer factory, Mr. Thompson is succeeded by MR. R. THOMSON, who joined B.T.H.—now A.E.I. (Rugby), Ltd.—in 1939 and was appointed assistant superintendent, transformer factory in May, 1956, and superintendent in October, 1957, a position he retained until his present promotion.

MR. F. P. LAURENS, assistant managing director, production, of International Computers and Tabulators, Ltd., has resigned from the board of directors of Vickers-Armstrongs, Ltd.

ELCONTROL, LTD. announce that MR. B. A. WORSWICK has been appointed to the post of technical director with a seat on the board. Mr. Worswick was until recently chief engineer of Fischer and Porter, Ltd., and previously was chief development engineer of Bailey Meters and Controls, Ltd., after having served for some years with I.C.I., Ltd.

THE First Lord of the Admiralty has approved the appointment of MR. P. T. WILLIAMS to be director of Navy Contracts in succession to MR. B. POOL, C.B., C.B.E., who is retiring.

VICKERS-ARMSTRONGS (ENGINEERS), Ltd., announce the appointment of MR. A. E. REDDELL, O.B.E., as a director and to the office of director-in-charge, Weymouth works, and of MR. F. A. E. PRITCHARD as a special director and to the office of general manager, Weymouth works. MR. J. FERGUSON SMITH has been appointed a special director of Vickers-Armstrongs (Aircraft), Ltd.

MR. A. NADIN has been appointed general manager of Brayshaw Furnaces, Ltd., and Brayshaw Tools, Ltd. A native of Sheffield, Mr. Nadin was, prior to his appointment as works manager with the Brayshaw companies in 1957, with Samuel Osborn and Co., Ltd. and their subsidiaries.

THE appointment of MR. J. L. LUTYENS as group director of research, with a seat on the board of the Motorcar

Body Division, has been announced by the Pressed Steel Co., Ltd. Mr. Lutyens began his industrial career with Aluminium Union, Ltd., joining the British United Shoe Machinery Co., Ltd., in 1949, and rising rapidly to the position of director of research.

Mr. K. W. SIMS has been appointed export promotion manager of C. C. Wakefield and Co., Ltd., parent company of the Castrol Oil Group.

Mr. H. W. A. WARING, C.M.G. managing director of Brymbo Steel Works, Ltd., who was recently elected to the board of the parent company Guest, Keen & Nettlefolds, Ltd., has been re-elected chairman of the Steel Committee of the Economic Commission for Europe for a second year. He is the first British chairman.

CONSEQUENT upon the acquisition by The British Rollmakers Corporation, Ltd., of the whole of the issued share capital of Richard Lloyd, Ltd., Mr. D. FEATHERSTONE DODD, T.D., and Mr. R. H. HIGGS, J.P., have been appointed directors of The British Rollmakers Corporation, Ltd.

Mr. E. HARTLES, commercial director of McKechnie Brothers, Ltd., has been appointed assistant managing director of the company.

FOUNDRY SERVICES INTERNATIONAL, LTD., announce that Mr. B. H. WILLIAMS has been appointed a director of their Australian company, Foundry Services Australia, Pty., Ltd. Mr. Williams joined the Foseco organisation in 1951 and in 1958 went to Australia as general manager of the Australian company. Mr. R. W. FLINT, who joined Foseco in 1950, has been appointed general manager of the associated Indian company, Greaves Foundry Services Pte., Ltd.

Mr. A. E. STURDY, M.B.E., who has been secretary of the Russo-British Chamber of Commerce (Inc.) for the past twenty-five years, has retired at his own request on reaching the age of 65. Mr. H. E. S. HAYWARD, the assistant-secretary has been appointed to succeed him.

Mr. E. P. COLLINS, advertising manager of The Morgan Crucible Co., Ltd., and its associated companies has recently been elected hon. secretary of the Incorporated Advertising Managers' Association. Mr. COLLINS has been a member of the Society for thirteen years and was recently awarded a Fellowship for his services to advertising and to the Association.

Mr. F. W. TOMLINSON, managing director of Pyrotenax, Ltd., Mr. J. M. WILLEY, director and general manager of Murex Welding Processes, Ltd., and Mr. P. S. BRYANT of Murex, Ltd., have been appointed to the board of Murex, Ltd., Rainham. Mr. Tomlinson has also been appointed to the board of Murex Welding Processes, Ltd., Waltham Cross.

THE Messel Medal, the senior award of the Society of Chemical Industry, which is awarded every two years for meritorious distinction in science, literature, industry or public affairs, will be presented to the medallist for 1960, THE RT. HON. THE VISCOUNT CHANDOS, D.S.O., M.C., in Bristol on Wednesday, 6th July next, during the Annual Meeting of the Society.

At the meeting of the board of directors of Brymbo Steel Works Ltd., on 29th January, it was announced that Mr. A. F. GADSBY had resigned his directorship at the end of last year, due to pressure of other work. Mr. Gadsby was one of the original directors elected to the board of the present company when it was incorporated in 1948, at the time when the company became a member

of the Guest, Keen & Nettlefolds Group. At the same board meeting, Mr. P. H. MEADOWS, who has held various positions at Brymbo since 1938, and who has been the company's secretary since 1953, was appointed a director.

BRITISH INSULATED CABLES LTD., announce that Mr. T. C. JOHNSTON, formerly general manager of Metropolitan Electric Cables and Construction Co., Ltd., has joined the company as regional manager (Eastern region).

Mr. D. W. HOPKINS, head of the metallurgy and chemistry department at Swansea Technical College, has received one of the first four awards, announced by the English-Speaking Union in London recently, to try out a plan foreshadowed by the Duke of Edinburgh at Ottawa. The plan is for the exchange of teachers in technical colleges here with their opposite numbers in the U.S., and it begins with a pilot scheme covering an eight-week's stay in America.

Mr. W. F. LIST, assistant managing director of C. C. Wakefield & Co., Ltd., and of Wakefield-Dick Industrial Oils, Ltd., recently completed fifty years with the Wakefield Castrol Group. Mr. List joined Wakefields straight from school, and in 1922 he was appointed manager for India, a position he occupied for ten years before being transferred to the managership of the South African branch. In 1946, Mr. List returned to England to become overseas general manager and, one year later, was elected to the board. He was appointed to his present position of assistant managing director in 1952.

Obituary

WE regret to record the death of Mr. W. DEWHURST, who has died at the age of 59 in a Sheffield hospital. He had been with Newton Chambers & Co., Ltd., Thorncliffe, Sheffield, since 1947 and was their Engineering Division's sales representative concerned with iron and steelworks plant. Mr. Dewhurst was educated at Dronfield Grammar School and Sheffield University, and was a member of the Iron and Steel Institute. Straight from University he served in the Royal Field Artillery during the First World War, and on demobilisation in 1920 he joined the family firm, The Dewhurst Engineering Co., Ltd., Sheffield, and worked as a draughtsman and later as a sales representative with that company until 1931. It was in 1931 that Newton Chambers took over the goodwill of the iron and steelworks plant business of the Dewhurst company.

Mr. Dewhurst went to Germany in 1932 taking a post as an engineering inspector of railway stock. He was associated with the Turkish State Railways and from his headquarters in Essen travelled extensively through Germany and Czechoslovakia. Just before the outbreak of war in 1939 he returned to England and for a year or so, was London representative of the Leystol Engineering Co. Mr. Dewhurst joined the Ministry of Labour and National Service as a Labour Supply Technical Officer in 1941, and it was from that position that he joined Newton Chambers in October 1947. At first he was the section leader dealing with iron and steelworks plant, but when his health began to deteriorate he preferred to go out on the road. His contacts and friendships throughout the iron and steel industries helped to make him one of the most successful as well as most popular of representatives.

Lighting-3

Data Sheet No. 7 dealt with some actual applications of factory lighting. Further applications are given here.

Drawing Offices

It is fair to say that in no part of a factory is good lighting more important than in the drawing office. The draughtsman's task is extremely exacting and unless the illumination is up to required standards, mistakes, loss of time and greater fatigue will result.

The essential requirements are:

- High value of illumination
(minimum of 30 foot-candles on the boards)
- Absence of shadows
- Absence of reflection

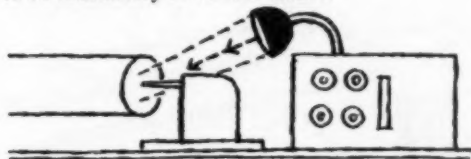
One of the major problems is the reflection of the light sources by shiny tracing paper, instruments, set-squares, etc., and particularly by the extra-hard pencil leads often used. Another problem is that caused by the shadows ahead of T-squares and by the variety of angles at which drawing boards are set.

Fluorescent lighting is particularly suitable because of its comparative freedom from shadow, its natural colour and because it can be localised with respect to drawing boards to avoid reflections while at the same time giving enough light upward and sideways to satisfy the general lighting requirements of the office.

A lighting solution which has been successfully employed for tracing is to light from beneath and through the paper which is fixed on to a translucent panel, thus eliminating the problems of shadow and reflection.

Machine Shops

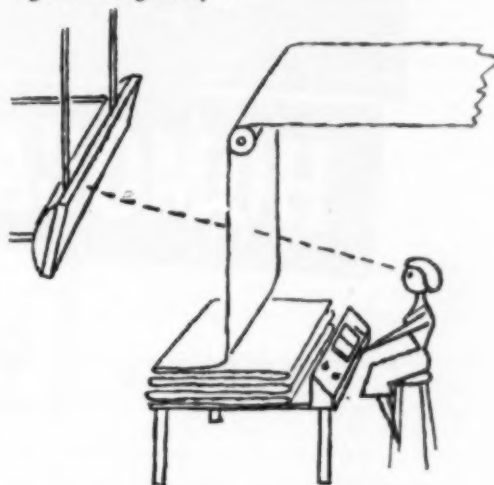
The problems of machine-shop lighting vary so widely that it is impossible to lay down rigid rules which are applicable to all types of machine. Much of the design of such lighting systems must therefore be a matter of individual application. Certain maxims, however, have proved in practice to be satisfactory in various trades.



There is a strong case for the provision of local lighting on many machines to enable the direction of light to be varied to suit the work, or to boost the illumination for fine work.

In shops employing certain machine tools, particularly circular saws, the possibility of stroboscopic effects can be avoided by splitting lamps among the phases of a three-phase supply or by using twin lamp fittings with a split-phase circuit.

Where safety goggles are used, extra illumination should be provided to compensate for the reduced light reaching the eyes.



Silhouette inspection of fabrics or profiles can often be used to advantage by placing a light source behind the material to be inspected — on the lines of the back-lighting already referred to for tracing in the drawing offices.

In general, machine-shop lighting is essentially an empirical science, based largely on a combination of general and local lighting, which offers immense scope for ingenuity.

Outside Lighting

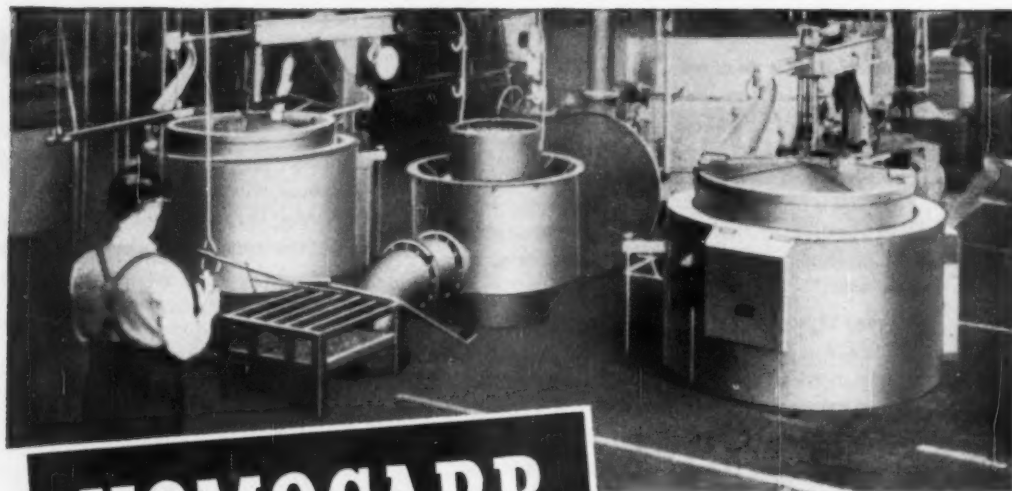
The outside precincts of a factory are often much neglected. No special rules can be suggested for lighting these areas, but speed, efficiency and safety are all dependent on adequate outside illumination during the hours of darkness.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each or 9/- post free) are available—"Lighting in Industry" is an example.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity, including one on industrial lighting. Ask for a catalogue.

7932



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RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

High Temperature Sintering Furnace

A NEW heavy duty sintering furnace for operation at temperatures up to 1,650°C. with a hydrogen atmosphere has been designed and manufactured by Royce Electric Furnaces, Ltd., for a special application.

The heating chamber is a replaceable tube of fused alumina 5 in. inside diameter, 32 in. heated length. Fused alumina tiles housing the heavy-section molybdenum heating elements surround the tube and support it along the heated length, allowing free dissipation of heat and providing mechanical strength. A special high temperature insulation of porous alumina behind the bricks is backed by graded thermal insulation, reducing heat losses to a minimum. A mechanical failure of the work tube, due to thermal shock or stress from the charge load does not, with this new arrangement, cause failure of the heating elements. Conversely, the work tube is unaffected by an electrical failure of the elements, which can be replaced individually in the segmental pure alumina tiles. A further advantage of this new design is that considerable sensible heat is absorbed in the refractory lining, acting as a heat reservoir. This serves to even out the heat distribution and, coupled with the mechanically strong construction, makes the furnace very suitable for heating heavy loads.

The cylindrical furnace casing is constructed of heavy gauge mild steel plate, with removable end covers, the whole being gas-tight. At the charging end, an extended solid drawn tube acts as a preheat-purging chamber; the exit chamber is water-cooled to ensure that a charge is below oxidation temperature before leaving the furnace. Atmosphere of hydrogen or cracked ammonia is fed through an inlet under the furnace to distribution pipes in the thermal insulation in the base. The gas percolates through the insulation, absorbing heat, and is thus preheated before entering the work tube. Auxiliary inlets are provided in the main furnace casing and between heating and cooling chambers to allow an increase in the gas flow when doors are opened for charging

or discharging. A 'burn-off' at both doors consumes excess hydrogen and prevents ingress of oxygen.

The heating chamber is divided into two independent automatically controlled zones along its length. Automatic temperature control, mounted in a separate control desk, comprises three-position indicating-type temperature controllers operating motorised voltage regulators giving stepless variation of the low voltage element supply. By this means the current is not switched off when controlling at the pre-set temperature. The secondary voltage of the motorised regulator is automatically adjusted so that the power input to the furnace balances the consumption. This method gives a very smooth control, eliminating fluctuations that may be obtained with 'on-off' control. Similar units are in operation with transducer control. Provision is included for hand control when required. The furnace is rated at 25 kW., and is arranged for operation on a three-phase supply.

A charge of piece parts in alumina powder in a carbon boat 12 in. long, has a gross weight of 14 lb. The boats are progressed through the preheat, heating and cooling chambers by a hand pusher, or by a cycle-timed automatic pusher ensuring repeatability of the sintering cycle,

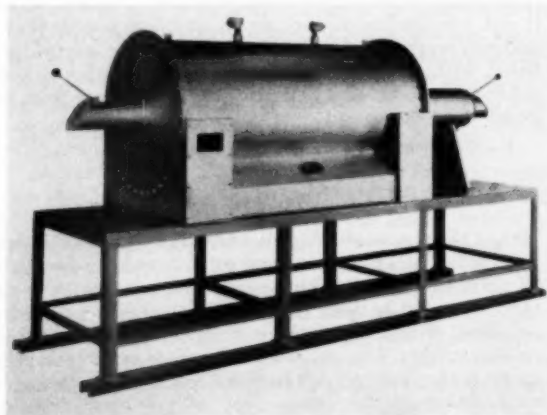
Royal Electric Furnaces, Ltd., Sir Richards Bridge, Walton-on-Thames, Surrey.

Lightweight Welding Blowpipe

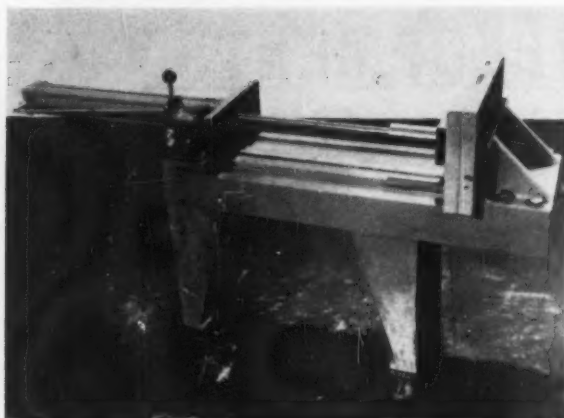
A NEW welding blowpipe of exceptional lightness now being marketed should prove of particular value in reducing operator fatigue. Manufactured by British Oxygen Gases, Ltd., the new blowpipe is an extension to their range of equipment specially developed for welding sheet metal and for light welding repairs, such as to car bodies and fittings. Known as the Light Weight Saffire, the blowpipe, completely assembled to include one of the standard range of nozzles, weighs only 9½ oz. It has forward-mounted controls for easy adjustment, and is 13¼ in. long. The blowpipe has a new type of mixer assembly specially designed to provide a stable flame and resistance to back-fires over the whole working range. The normal range, which is covered by six nozzles, permits welding of sheet steel up to ⅜ in. thick, but three additional nozzles are available for thicknesses up to ⅝ in.

The inlet construction and valve blocks are machined aluminium stampings, while the gas tubes are drawn aluminium. The handle valves are aluminium die castings, and the assembly is finished by polishing and clear anodising. The gas control valves are of the fine adjustment type, with stainless steel spindles and the gland caps are of polished chromium-plated brass. The control knobs, which are fluted in shape, are made of anodised aluminium suitably colour coded. The length of the shank is 6½ in. and its weight 6½ oz.

The assembly follows the basic Saffire pattern and, compared with existing lightweight blowpipes, is of an improved design which results in better gas mixing and greater resistance to back-fire. It is made entirely of brass. The nozzles are of swaged copper construction



High temperature sintering furnace.



Gravity die casting machine with mould closed ready for pouring.

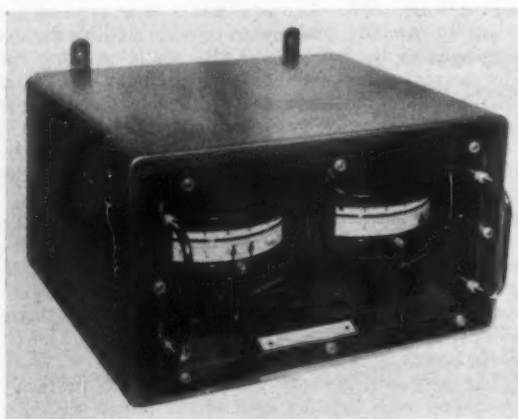
with accurate smooth internal bores produced by a special swaging process. All but the two largest sizes are $9\frac{7}{8}$ in. long and weigh 1 oz. The design of the nozzles leads to a good balance in the blowpipe and flame stability.

British Oxygen Gases, Ltd., Spencer House, St. James's, London, S.W.1.

Gravity Die Casting Machine

A SIMPLE die casting machine which uses inexpensive dies and can be operated without previous die casting experience has been introduced by the Foundry Division of Electric Resistance Furnace Co., Ltd. It has been designed to reduce both the capital and running costs of producing iron and light metal castings which do not need to be made within close dimensional tolerances.

The machine has a two-way cylinder for closing and clamping the dies and requires only a supply of compressed air for its operation. The die heating and cooling arrangements of conventional die casting machines are not required, as the dies are made in a grade of Meehanite



Two West Instrument resistance controllers in corrosion proof cabinet for use on an oil barge in the Persian Gulf.

metal to withstand thermal shock and the machine is used in banks of sufficient numbers to allow time for natural cooling. For making iron castings weighing about 3 lb., the dies require a cooling time of about 4 min. In this time two operators, one pouring and the other removing the castings, can tend fifteen machines and produce 225 castings an hour. Dies are designed by the company from customers' drawings and supplied ready for insertion into the casting machine. They are made by the 'true to form' as cast technique at approximately one quarter the cost of machined dies.

The EFCO die casting machine has an overall length of 3 ft. 10 in., is 9 in. wide, and stands at a convenient height for pouring. It will accommodate dies up to 10 in. by 8 in. in face area. A bank of five machines with gangways and stillage/bogie room occupies a floor space of about 8 ft. by 8 ft.

Foundry Division, Electric Resistance Furnace Co., Ltd., Weybridge, Surrey.

Sub-Zero Temperature Control

WEST INSTRUMENT, LTD., have recently started manufacturing a resistance temperature controller and indicator of entirely new design which takes them into the field of low-temperature control. This company has, until now, specialised almost entirely in instruments for control at temperatures above 200°C . The new instrument, which is available with stepless, proportioning and on/off control, is suitable for a wide span of operating temperatures, and offers precision control and indication to below -100°C .

A prominent feature of the new instrument, is the built-in rectifying and stabilising unit, fed direct from A.C. mains, instead of the usual battery arrangement. This enables the controller to be used at any time without the necessity of making lengthy adjustments to compensate for battery deterioration, and it enables surprisingly compact dimensions to be achieved; (the frontal measurements of the resistance on/off controller, for instance, are only $7\frac{1}{2} \times 6\frac{1}{4}$ in.).

For small changes in temperature, there is a substantial change in the current flowing through the meter, consequently a robust meter movement can be used without sacrificing sensitivity and accuracy. The scale of the resistance controller can quite conveniently have an artificial zero, facilitating accurate setting and indication even at extreme temperatures. The instrument is not susceptible to changes in ambient temperatures, and will work satisfactorily at 130°F . The controller is fitted with either a three or four lead resistance bulb, enabling it to be used at considerable distances from the point of measurement.

West Instrument, Ltd., Brighton.

Polythene Buchner Funnels

ONE of the outstanding applications for plastic laboratory ware is the polythene Buchner funnel, which is less liable to thermal shock cracking than the porcelain type and more resistant to mechanical shock than either porcelain or glass. The first polythene Buchner funnels to appear on the market were fabricated from standard polythene sections by welding, and they did not always come up to expectations. The latest type of polythene Buchner funnels now offered by Goodburn Plastics, Ltd., are claimed to show none of the disadvantages previously

encountered and it is expected that they will supersede all other types of Buchner funnels previously used. They should not, of course, be employed with organic solvents, nor with water near its boiling point; in fact they should not be used for temperatures exceeding 80° C. The new type funnel consists of two parts; the filter disc fits snugly into the lower part (funnel) and they can thus be separated quite easily for cleaning purposes. They are supplied in three sizes to fit filters of 11, 15 and 24 cm. diameter.

Goodburn Plastics, Ltd., Arundel Road, Trading Estate, Uxbridge, Middlesex.

General Purpose Balance

THE first of a new series of balances designed for general purposes but incorporating analytical features, has been produced by Griffin and George, Ltd. The Griffin Minor has a short beam for speedier weighing; single-limb bows carrying the weighing pans for unimpaired operation; an inclined scale which rises with the pointer, thus facilitating reading and avoiding parallax; a unique design in stirrups to protect knife edges; and a new design pillar allowing easy and rapid assembly. The improved assembly of the agate bearings is an important feature, because they are held in position by screws instead of being "drifted in" which is the usual practice. When the beam is arrested all the agate bearings are relieved; usually only the central bearing is. This modification ensures much longer life with students and in works control laboratories.

Griffin and George, Ltd., Ealing Road, Alpertown, Wembley, Middlesex.

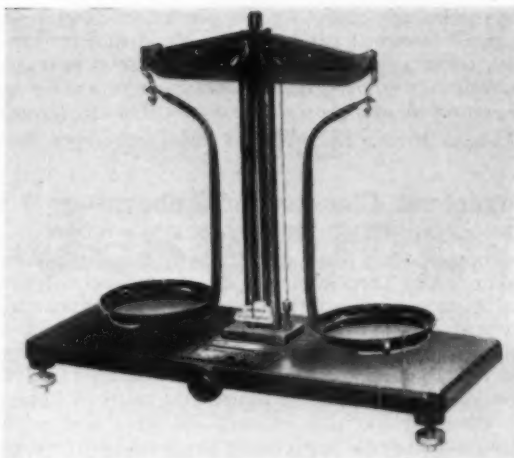
Low Pressure Enamel Spraying

THE use of vitreous enamel today is steadily increasing, and any improvement in technique which leads to a reduction in production costs is of major importance to the industry. Following extensive tests and development work in conjunction with Ferro Enamels, Ltd., Alfred Bullows & Sons, Ltd., have produced equipment for applying vitreous enamels at very low air pressures.

This technique of low pressure enamel application offers several major advantages to the enameller. Firstly, there is a definite economy in enamel used. Secondly, with a low pressure nozzle it is a simple matter to obtain a very fine coat, which when fired, is far less brittle than a thick enamel coat would be. Thirdly, the low pressure technique requires far less skill than normal production methods. Finally, when spraying hollow objects, such as bread bins, spin dryer bowls etc., "bounce" is a serious problem at normal pressures. Using the low pressure technique the job is easy.

Suitable nozzles have been developed for this purpose on the L.1900 Bullows-Binks Model 19 and the L200 Model 2 spray guns. When using the L1900, best results are obtained with fluid pressures varying between 5 and 12 lb./sq. in. and with an air pressure of 25 lb./sq. in., using 63B x 66PH set-up. With the L200, a fluid pressure of 5 lb./sq. in. and an air pressure varying from 25 to 50 lb./sq. in. can be used, using A39 x A5P set-up. The material used for all tests was a standard cover coat enamel having a specific gravity of 1.34 and a fineness of 34/200/50.

A parallel development resulting from these tests was that, whilst mottling in the vitreous enamel trade has



The Griffin Minor balance.

generally been considered a slow process, an enormous increase in speed is possible with the L200 spray gun. A fluid pressure of 5 lb./sq. in. and air pressure of 8 lb./sq. in. is used with the A39 x A5P nozzle set-up.

Alfred Bullows and Sons, Ltd., Long Street, Walsall, Staffs.

Mercer-Saxl Tension Meter

MESSRS. THOMAS MERCER, LTD., have acquired the U.K. manufacturing rights of the Saxl tension meter from Messrs. Tensitron Inc., of Harvard, Mass., U.S.A. Although mainly used in the textile industry for the inspection of yarn tensions, this instrument is widely used in many branches of industry where accurate or known tension of tape, wire, cord, nylon, etc., is desired.



Mercer-Saxl tension meter.

It is particularly useful for the precise winding of wire for small electrical components. Made in four types, which cover a range of 0-1,000 g., the meter is trigger-operated, has grooved tension and guide rollers for ease of application, and gives stable readings in any position.

Thomas Mercer, Ltd., Eyewood Road, St. Albans, Herts.

Ultrasonic Cleaner for Laboratory Use

ALTHOUGH ultrasonic cleaning is a relatively recent development, it is based on the theory of cavitation first expounded by Lord Rayleigh, and the magnetostrictive transducer used relies on the work of Joule 122 years ago. A new product in this field is the Rapideclean 1, developed and marketed by Ultrasonics, Ltd. This is a high power unit for laboratory use, for which a number of advantages are claimed. At the chosen frequency of 13 kc./s. the energy conversion is very efficient, and as the transducer material is virtually unaffected by moderate heating it is possible to work at temperatures above the boiling point of water. Work done on the Rapideclean can be reproduced in larger installations, so that it is very suitable for exploratory tests. With its beaker set neatly on top of the cabinet at a convenient height, the Rapideclean is a complete unit, taking up little space on the bench. Only 18/8/3 stainless steel is in contact with the cleaning media and the simplicity of the design reflects in the price, whilst simplicity of operation is implied by the incorporation of only one switch, one control light, one meter and one tuning knob.

Ultrasonics, Ltd., Westgate, Otley.

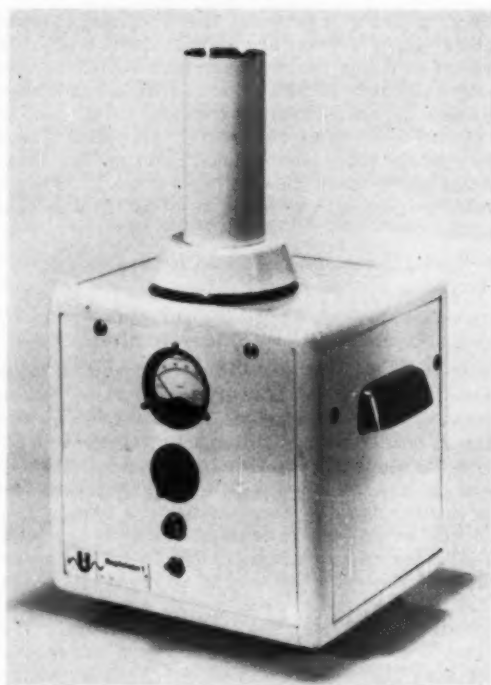
Transistorised Recorder

THE Fielden Capacipoise Servograph is a servo-operated recorder designed to fit into the Capacipoise range of instruments. These operate from a supply of 12 V. D.C. but are available in two models, one requiring an external D.C. supply and the other incorporating its own power pack, which may be operated from the normal 240 V. 50 c./s. mains supply.

The size of the instrument has been chosen to give a chart 6½ in. diameter, which is large enough for the vast majority of applications, whilst the recorder itself will occupy a minimum of panel space. All instruments are fitted as standard with a central indicating pointer moving over an arc of 300°. The indicator scale has a length of approximately 15 in. and is easily readable from a considerable distance. One or two electrical contacts, which can be used for alarm or control purposes, can be fitted and other forms of control are also available. Both the pen and the indicating pointer are motor driven, and no errors are introduced by pen to paper friction or by the weight of the pen. The servo-motor also ensures that extremely small increments are faithfully reproduced on the chart.

In the design of the recorder, moving parts have been reduced to the absolute minimum. Gearing between the servo-motor and the central indicating pointer has been eliminated by the use of a rim drive, and a simple quadrant connects the indicating pointer to the recording pen. With this new modern design it is claimed that the instrument is very much simpler than are conventional servo-operated recorders and can be depended upon to give long, trouble-free service without attention.

Since the input is isolated from earth, the Servograph



Rapideclean 1 ultrasonic cleaner.

can record any current or voltage normally indicated on a meter and is quite suitable for recording the output of other electronic or electrical equipment such as pH meters, smoke density detectors, CO₂ indicators, beta gauges, tachometers etc. The minimum full scale deflection is 25µA. or 30 mV.

Fielden Electronics, Ltd., Paston Road, Wythenshawe, Manchester 22.

Photoelectric Temperature Controller

A NEW photoelectric low temperature Pyrostat has been designed by Radiovisor Parent, Ltd., to increase the range of temperature control possible by the use of their standard Pyrostat unit, which has been employed on industrial heating applications over a temperature range of 750°-1,500° C. The new equipment incorporates all the technical features which have been proved in factory use with the high temperature unit, the accent being placed on robustness, simplicity of adjustment and stability in operation.

The main use for the low-temperature Pyrostat—which is suitable for control in the 300°-800° C. temperature range—is on induction and resistance heating operations where the temperature rise of the workpiece is extremely rapid. Due to improved heating techniques faster heating cycles have been achieved and this, combined with tighter specifications on alloy steel heat treatment, has made precise control imperative. To obtain this a control device working directly from temperature is necessary in preference to an inferential method of control such as a time cycle, which can vary due to alterations in the main load.

Radiovisor Parent, Ltd., Stanhope Works, High Path, London, S.W.19.

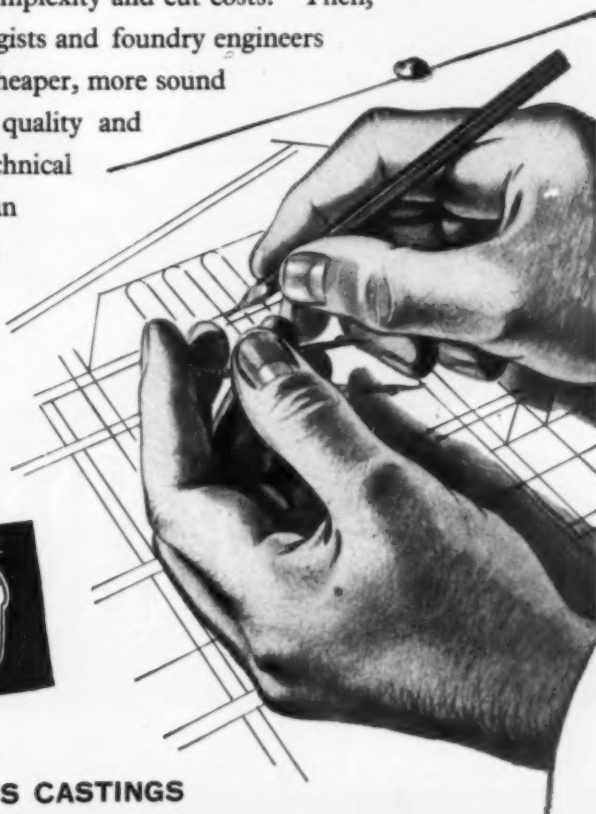


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LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

FEBRUARY, 1960.

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The Non-Destructive Metallography of Tin and its Alloys

By Dr. Pierre A. Jacquet

Development of an electrolyte free from water has made possible the electrolytic polishing, with the aid of an electrolysing pad, of tin, lead, tin-lead alloys and a variety of bronzes. Combined with the use of replicas, this technique makes possible the study of the micro-structure of large masses of these materials without the necessity for cutting sections.

Typical examples of its use are illustrated by a number of photomicrographs.

THE technique of non-destructive metallography possesses, among other advantages, that of avoiding the taking of small samples when it is desired to study the superficial structure of objects of particular shapes and sizes. The technique, described for the first time in 1956,^{1,2} requires, on the one hand, local electrolytic polishing by means of an electrolysing pad in order to prepare the selected portion of the surface and, on the other, a replica process which allows of the original surface being substituted by a transparent nitrocellulose varnish imprint. While the replica method is, in general, suitable for surfaces of all kinds and for all metallic materials, the conditions for local electrolytic polishing have to be adapted to the particular metal or alloy.

Up to the present time, it has not been possible to polish by the electrolysing pad, tin, lead, and alloys containing them, although electrolytic polishing by the simple cell method has been known and used for a long time.³ The difficulty met with there stems from the practically

instantaneous re-deposition of the metal on the cathodic electrolysing pad, which results in the short-circuiting of the two electrodes. With bronzes containing up to 25% tin, the position is made even more difficult by the fact that there is no method of electrolytic polishing which is really satisfactory. Thanks to the perfection of a new electrolyte characterised by the total absence of water (reference "Perac" with the Ellopol technique), the author has recently succeeded in solving the problem of polishing with the electrolysing pad the following metals: tin, lead, tin-lead alloys, and a variety of bronzes. The object of the present article is to present a brief description of the method of working, which is applicable, of course, to the preparation of the usual small samples. At the same time, details are included of the making of replicas, and some examples are given of the results obtained by these two processes.

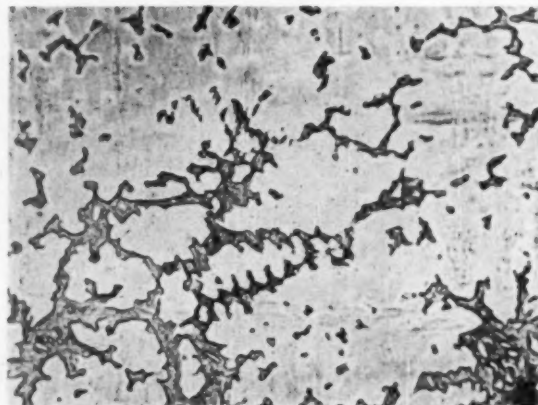
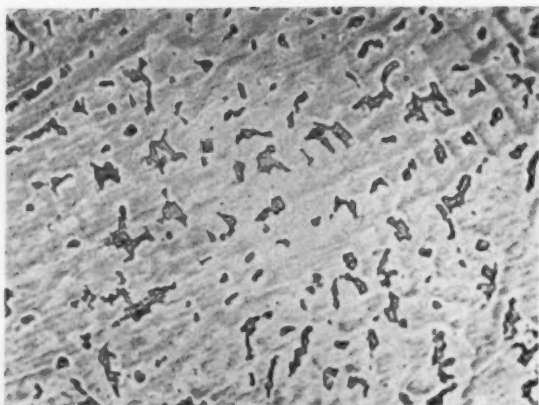
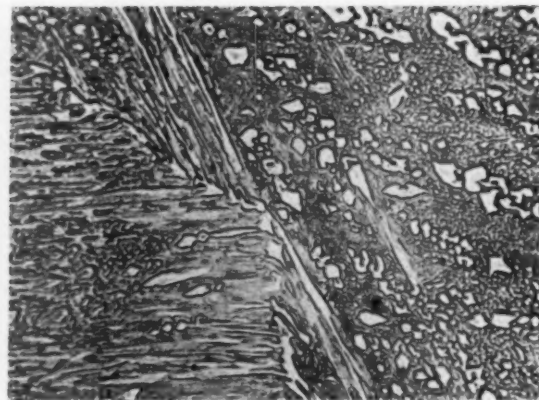
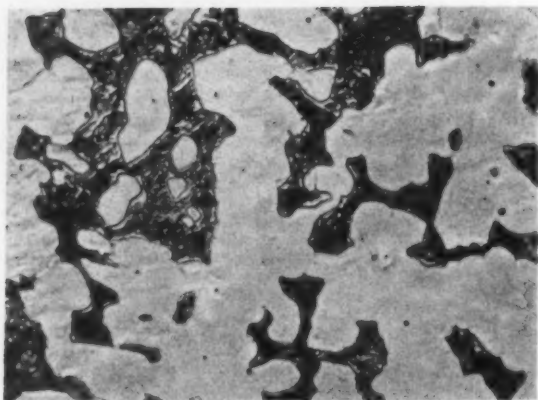
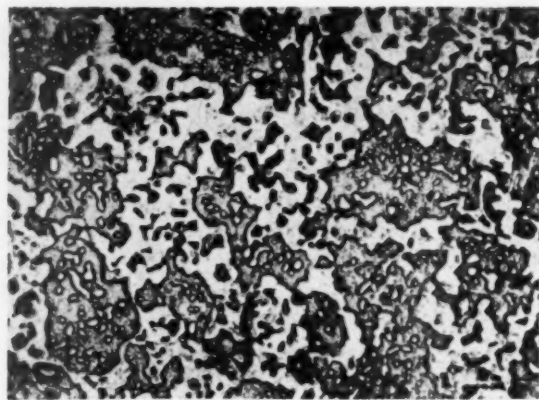
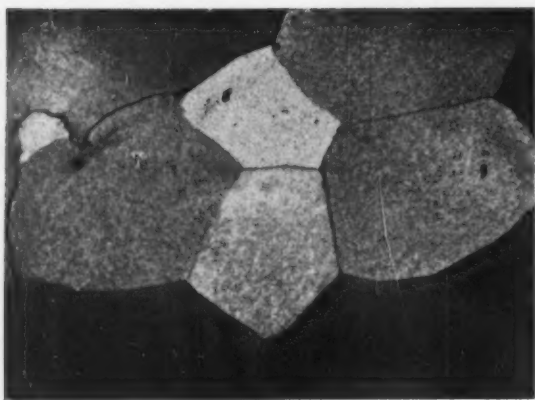
Local Polishing

The local polishing equipment known as Ellopol (Fig. 1) has been devised to be transported easily for indoor or outdoor testing. It comprises equipment for the supply and regulation of current, and an electrolysing pad formed from a water-cooled metal head fixed to the end of an insulating sleeve. On this head, which is ogival, or pointed, is attached a pad of electrical insulating material, which is not attacked by the electrolytes, and which is sufficiently spongy to retain 5-7 ml. of liquid. The electrolysing pad, which functions as a movable cathode, is connected to the negative terminal of the apparatus, whilst a clip with a large jaw is connected to the other terminal source to make contact with the object.

When the specimen is thin, it must be placed on a massive support of copper or aluminium in order to avoid deformation and to assist its cooling. The method of operating is very simple. The voltage across the open terminals is fixed at the desired value (40-45 V. for all the bronzes containing no lead, and 32-34 V. for tin, tin-lead alloys and bronzes containing lead). The electrolysing



Fig. 1.—Simple equipment for non-destructive metallography: (left) Ellopol for local electrolytic polishing; (right) ordinary microscope and attachment for photographing replicas by transmitted light.



- Fig. 2 (top left).—Rolled pure tin, polished-etched for 10 seconds ; bare replica, photographed in reflected light. $\times 160$
 Fig. 3 (top right).—Cast 60% lead, 40% tin alloy ; bare replica photographed in reflected light $\times 160$
 Fig. 4 (centre left).—78% copper, 6% tin, 16% manganese alloy, near the edge of the section. $\times 1,000$
 Fig. 5 (centre right).—75% copper, 25% tin alloy (bell metal), near the centre of the section. $\times 1,000$
 Fig. 6 (bottom left).—88% copper, 10% tin, 2% zinc alloy (gunmetal), near the edge of the section. $\times 400$
 Fig. 7 (bottom right).—As Fig. 6, but near the centre of the section. $\times 400$

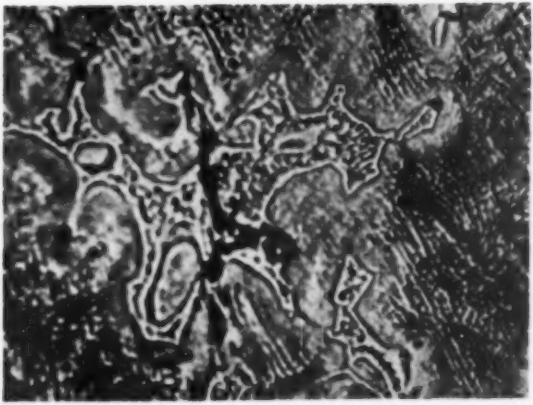
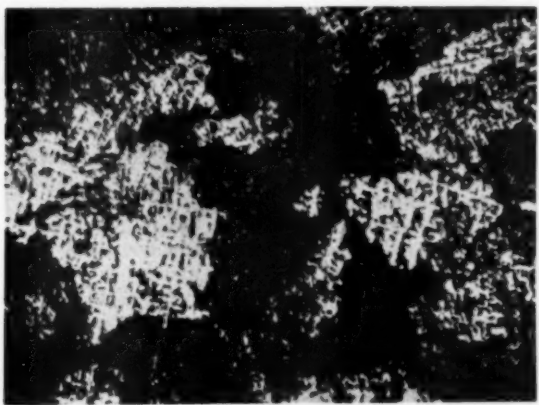
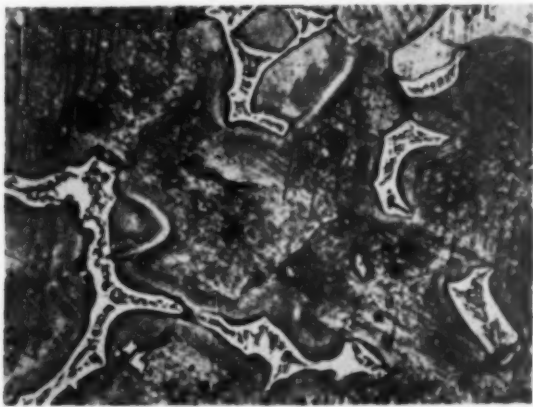
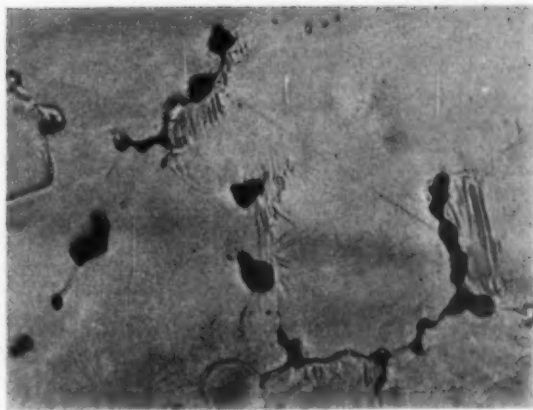
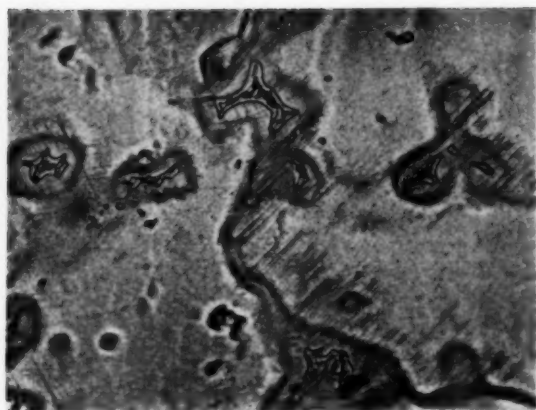


Fig. 8 (top left).—94% copper, 6% tin, 0.1% phosphorus alloy, near the edge of the section : etched for 45 seconds in a solution containing 0.5 g. sodium bichromate, 2 ml. sulphuric acid, 1 ml. saturated sodium chloride solution, and 122 ml. water. × 1,000

Fig. 9 (top right).—Casting defect in specimen used for Fig. 8, after polishing and before etching. × 1,000

Fig. 10 (centre left).—90% copper, 10% tin, 0.1% phosphorus alloy, near the edge of the section. × 1,000

Fig. 11 (centre right).—As Fig. 10, but etched for 20 seconds in the sodium bichromate solution. × 1,600

Fig. 12 (bottom left).—As Fig. 11, but metallised replica : photographed in reflected polarised light. × 63

Fig. 13 (bottom right).—As Fig. 12, but photographed in normal reflected light. × 1,600

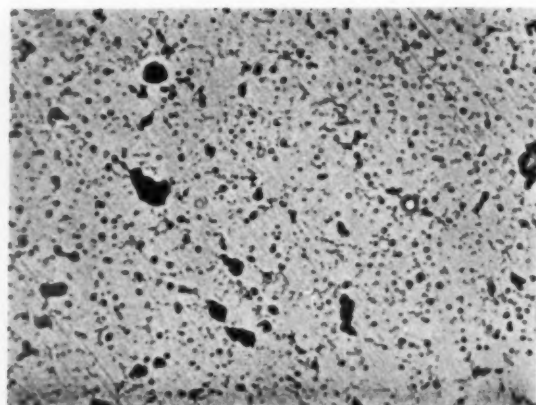
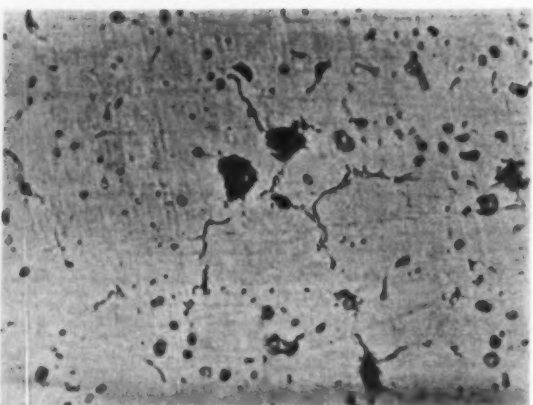
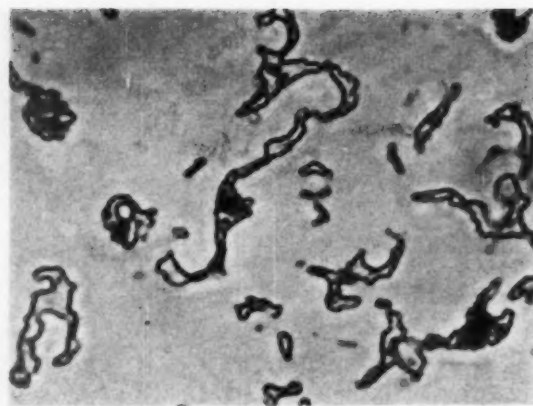
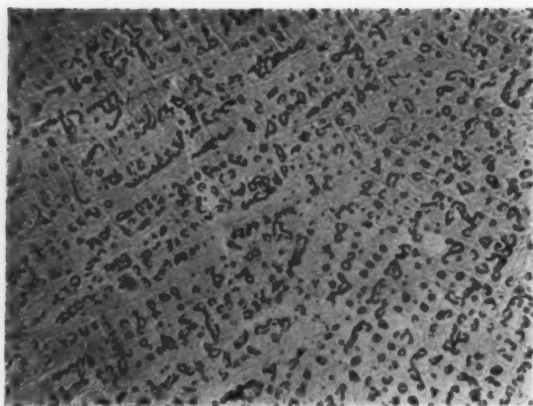


Fig. 14 (top left).—90% copper, 10% tin, 0.5% phosphorus alloy, near the edge of the section ; bare replica, photographed in transmitted light. × 160

Fig. 15 (top right).—As Fig. 14, photographed in transmitted light. × 1,000

Fig. 16 (bottom left).—75% copper, 5% tin, 20% lead alloy, near the edge of the section ; bare replica, photographed in transmitted light. × 400

Fig. 17 (bottom right).—80% copper, 10% tin, 10% lead alloy, near the edge of the section ; bare replica, photographed in transmitted light. × 160

pad is soaked in the electrolyte, without excess, and is applied by a succession of strokes. It is necessary to handle the electrolysing pad with a light touch, holding it very slightly above the metal surface, so as to hold a film of liquid between the two without actually brushing the specimen with the material of the electrolysing pad. For all bronzes a few very rapid strokes in the same direction suffice. With tin and tin-lead alloys, these conditions bring about a micrographic attack of variable intensity, but this can be avoided by increasing a little the duration of the last stroke.

Since excessive temperature rise is always disadvantageous, the total time of electrolysis should be as short as possible, and if necessary it can be carried out in two or three stages, each of 3–5 seconds duration, separated by rinsing and drying of the specimen between successive applications. Such a method of operating is especially important for certain bronzes which can give rise to a black powdery film. Because of the harmful effect of the heating, it is not possible to extend the area of the zone polished above that corresponding to the

contact of the pad, which is about 0.8 sq. cm., except for tin, where movement of the electrolysing pad is possible.

Except in the case of pure tin, the polished surface is wiped with a cotton swab during its wash under running water. Usually the washing is finished with a jet of alcohol followed by drying in warm air.

The electrolysing pad remains clean for a long time and need only be washed after use, but the metallic head should be wiped with a 0 grade abrasive paper at the end of each day's work. The pad after rinsing with running water, is left on the stove all night at not more than 50° C.

Replica Making

The special varnish Replic is applied to the specimen by pouring, or is squeezed from a dropper. After drying for 45–60 minutes in the ordinary air, or for 30 minutes under an infra-red lamp (temperature not more than 65° C.), the pellicule is lightly lifted along one edge and then placed in contact with a dilute solution of Teepol, either by immersion or with the help of a pad soaked in

the solution, if the object is too bulky for immersion. Usually after 10-15 minutes the film can be pulled off without risk of tearing it or of artefacts.

The replica is rinsed in ordinary water, then in distilled water while held in tweezers, prior to drying in a current of cold filtered air. The surface of the sample must, of course, be washed and dried.

The reader is referred to the author's earlier publications⁴ for details of the mounting, optical viewing and photographing of the replicas. It was mentioned at that time that one of the great advantages of the replica is its transparency, which allows the replacement of the normal metallographic equipment by more simple and less costly apparatus—for example, an ordinary projector for the macrography and an ordinary microscope for the micrography, which are much simpler to use when examining the structure of an ingot or of a fabricated article.⁵ Nevertheless, fine details at the greatest enlargement are better studied with the metallographic microscope, and in this case the face of the film carrying the impression is metallised in vacuum with a thin layer of aluminium or of gold. Finally, the bare replica can serve as a support for a counter-replica in carbon for electron micrography.⁶

Examples of Applications

Polishing with the electrolysis pad has been applied to pure tin in both the cast and rolled (1 mm. thick) state, to cast alloys of lead and tin (80/20 and 60/40), and to nine types of bronze in the form of discs taken from bars of 25 mm. diameter obtained by semi-continuous casting. All lend themselves to direct examination by the metallographic microscope and, consequently, the micrographs made with the aid of replicas, whether bare or metallised with aluminium, and whether by transmitted or reflected light, are reproduced here as bases of comparison.

With the exception of the rolled tin, which was polished directly, all the specimens were ground on emery papers Nos. 220 to 600, moistened with water, and were then finished on grade 00 paper with paraffin. Unless otherwise stated, the micrographs reproduced here correspond to a state produced by polishing for eight to twelve seconds.

Without going into further detail, the following points should be emphasised:—

- (1) The quality of the polish is excellent for tin and bronze without lead and with low phosphorus content. On the micrographs of the ordinary surface and on the replica (Figs. 10, 11 and 13) will be noted the good definition of the eutectoid and of the Cu_3P constituent.
- (2) Tin reacts well to polarised light, a property which is imparted to the replicas provided that the crystals have undergone sufficient etching. The same is true of bronze which has been etched chemically after polishing (Fig. 12). This confirms results obtained with other metals.⁷
- (3) In the 60/40 tin-lead alloy the eutectic slightly below the level of the matrix is perfectly resolved, even at the highest enlargements.
- (4) With a 10% bronze containing 0.5% phosphorus, a certain relief in the case of the eutectoid and of the binary complex $\alpha\text{-Cu}_3\text{P}$ is difficult to avoid. This is of little consequence when using medium

enlargements, and is even less evident on the replicas (Fig. 15).

- (5) As would be expected, the lead dispersed in the matrix undergoes a selective dissolution, the more bulky elements appearing, however, to preserve almost their normal form (Figs. 16 and 17).

Conclusions

Having regard to its simplicity and its rapidity, electrolytic polishing with the electrolysis pad can be usefully applied to the metallography of tin, tin-lead alloys and bronzes. Moreover, it is the only process which, combined with the technique of transparent replicas, permits of examining pieces without destruction.* In the case of alloys in which the nature of the structural heterogeneities is particularly unfavourable, the quality of the polish would no doubt be improved by taking the surface preparation further, or, alternatively, by following the electrolytic process with an adequate mechanical finish.

* Encouraging results have already been obtained from archaeological objects from which the taking of a sample is often prohibited.

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Further A.E.I. Integration

THE successful design of many types of industrial electrical installation depends upon application engineering, including the co-ordinated selection of the electrical machines and design of the control schemes. Many years ago both the British Thomson-Houston and Metropolitan-Vickers companies set up specialist departments to carry out this work. When A.E.I. Heavy Plant Division came into being on 1st July, 1958, two such departments were formed in the Division, one at Rugby and one at Manchester, from similar departments already existing in BTH and M.V. These two departments have both continued to deal with the application engineering of complete electric drives for rolling-mills and mine-winders and associated installations, and effective co-operation between these two departments within the Division has now made it possible to unite them in a single new plant applications engineering department which, having the combined resources and experience of both, will give yet better service to the Division's many customers throughout the world.

Continuous Casting of Steel Slabs

THE continuous casting plant to be installed by The Steel Company of Wales, Ltd., as part of the latest development programme will be the largest of its type outside the U.S.S.R. A twin-strand unit, it will produce slabs from 27 × 6 in. to 48 × 9 in. and up to 21 ft. in length from basic Bessemer steel. The well-known B.I.S.R.A. process will be used and the plant will be supplied by Continuous Casting Co., Ltd., Weybridge, who are licensees for the B.I.S.R.A. continuous casting processes and are an association of Campbell, Gifford and Morton, Ltd., Davy and United Engineering Co., Ltd., and Newton Chambers and Co., Ltd.

Duty Remission on Instruments and Apparatus

IN reply to a question in the House of Commons last month, the President of the Board of Trade said that, in the light of a year's experience, some relaxation could be made in the arrangements announced on 9th December, 1958, in connection with the remission of duty on instruments and apparatus under Section 6 of the Import Duties Act, 1958. The Board of Trade would, in future, be prepared to consider applications for remission of duty in respect of instruments and apparatus where the amount of duty was £20 or more instead of £50. To simplify administration, the same minimum limit of £20 duty would also be applied to applications covering parts of instruments and apparatus.

The following are the details of the arrangements to which the President referred: they apply to goods ordered by a user on or after 3rd February, 1960. Duty may be remitted on the following instruments and apparatus and parts thereof if similar articles are not for the time being procurable in the United Kingdom:—

- (a) optical and scientific instruments and apparatus;
- (b) measuring and checking instruments and apparatus;
- (c) apparatus based on the use of X-rays or of the radiations from radioactive substances;
- (d) thermionic, cold-cathode and photo-cathode valves and tubes; and
- (e) discharge lamps.

Applications will be accepted only in respect of goods on which (a) the full rate of duty is 25% or more, and (b) the amount of duty chargeable at the full rate is £20 or more, provided that the goods are:—

- (i) a single instrument or apparatus with or without parts or accessories; or
- (ii) two or more identical models of an instrument or apparatus ordered with or without parts or accessories at one time by one user; or
- (iii) production or replacement parts for a single model of instrument or apparatus, which are ordered separately at one time by one manufacturer or user.

Bar Mill Modernisation

STEEL, PEECH AND TOZER, a branch of the United Steel Cos., Ltd., are to spend over £400,000 on the modernisation of their semi-continuous bar mill. Work has begun on the scheme, which is due for completion by August, 1960. The bar mill was laid down nearly forty years ago and the existing drive is through line shafting and gearing from a single 3,000 h.p. variable speed A.C. motor. In order to introduce greater flexibility into the mill's operation, it is planned to replace this drive with a number of separate variable speed D.C. motors, totalling 3,400 h.p., and to renew some of the rolling mill stands.

The first stand on the present mill is a pinch roll stand which is to be replaced by a modern 18 in. horizontal roll stand. The first two stands of the roughing section of the mill are also to be replaced by new 18 in. horizontal and vertical stands, respectively. The horizontal stands will be powered by a single 350 h.p. D.C. motor and the vertical stand by a 250 h.p. D.C. motor.

A series of paired drives is to be installed on the remaining mill stands. Thus, stands Nos. 3 and 4 will be

driven by a 600 h.p. D.C. motor, Nos. 5 and 6 by a 700 h.p. D.C. motor, Nos. 7 and 9 by a 750 h.p. D.C. motor, and Nos. 8 and 10 by a 750 h.p. D.C. motor. A new motor room is to be built to house all these drives, which will be supplied from 2,200 kW. of grid-controlled rectifiers.

Other features of the modernisation scheme include the installation of a flying shear after No. 6 roughing stand, the provision of a modern oil lubrication system throughout the mill, and the installation of a high pressure water system for billet descaling. The latter will make it possible to improve the surface condition of the rolled bars, particularly in the case of material destined for bright drawing.

Main contractors are the Brightside Foundry and Engineering Co., Ltd., Sheffield, while the electrical equipment, including the motors and rectifiers, will be supplied by Associated Electrical Industries (Rugby) Ltd.

Nash and Thompson Expansion

NASH AND THOMPSON, LTD., have acquired a second factory within 200 yards of their present research and production unit in Oakcroft Road, Chessington, Surrey. This new factory has increased the available space by 35,000 sq. ft. and the transfer of administrative departments, research and development and some production departments has now been completed.

The purchase of this property was made necessary by the continued expansion of production and development during the last few years. More than thirty new instruments have been added to the range of standard instruments during the last two years. These instruments include many of the well known Nashon range of miniaturised electronic test equipment, several metallurgical instruments, equipment for survey work, plant and components for process control, a crystal pulling furnace, and scintillators.

An interesting fact of the company's work is that they are the only firm having a contract, now in the sixth year with the Ministry of Supply, for the environmental testing of components to R.C.S.C. and similar standards. Much of the work of this department is also for commercial companies in the electronics industry who require an independent report on the reliability of their products.

Electrical Equipment for Ravenscraig

A COMPREHENSIVE contract for all the electrical equipment in three steel rolling mills has been awarded to English Electric by Colvilles, Ltd., for their new Ravenscraig plant, near Motherwell, the biggest industrial project ever undertaken in Scotland. All the equipment will be engineered by English Electric's Metal Industries Division and mainly manufactured at the company's Stafford works.

Most important of the three mills is the semi-continuous hot strip mill. Besides light plate this will produce hot coiled strip which will be further rolled into sheet steel for cars and domestic appliances. The strip mill will be fed from the universal roughing and slabbing mills, both of which are of the hot reversing type with twin-drive motors. On the slabbing mill these will have a total of 14,300 h.p. and on the roughing mill 10,500 h.p. For distribution of power within the plant the company is also supplying seventeen 1,500 MVA. 33 kV. air-blast circuit-breakers.

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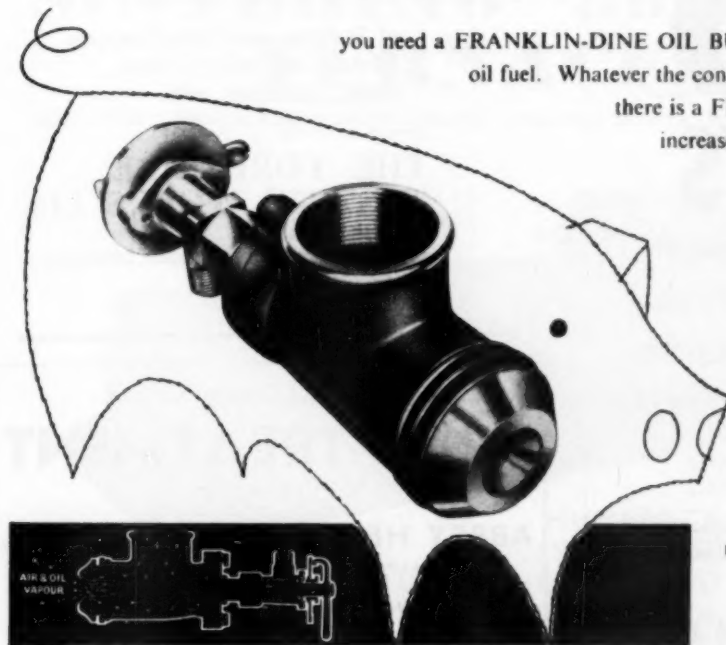
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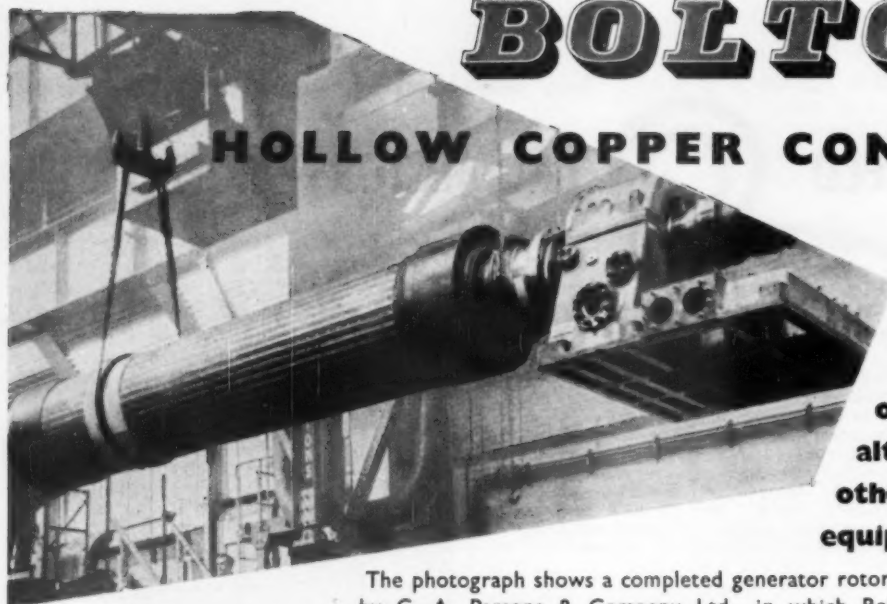
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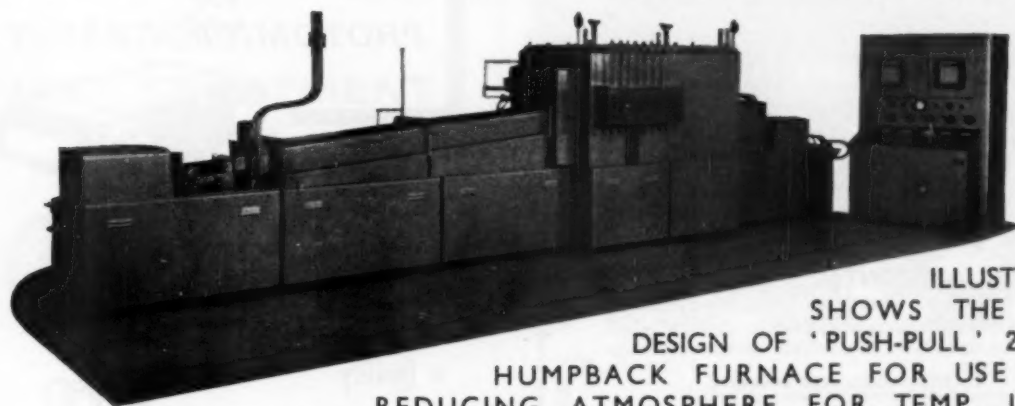


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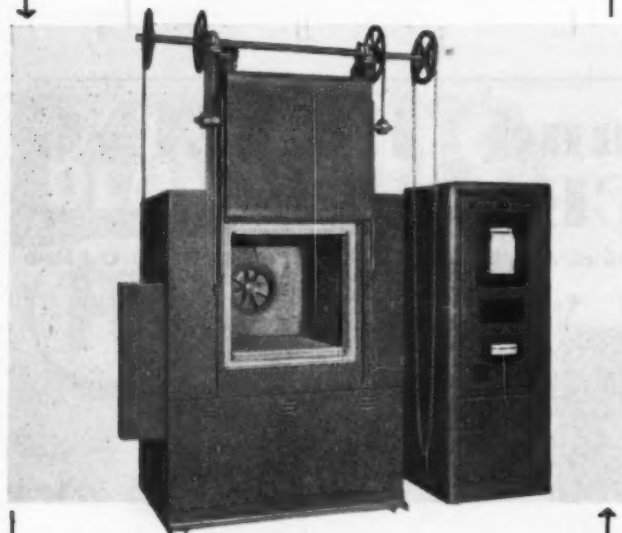
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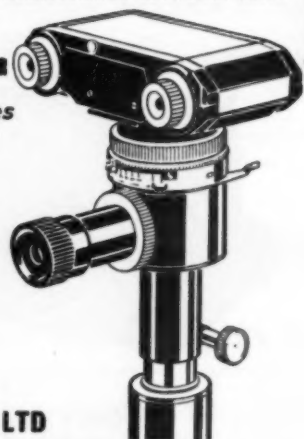
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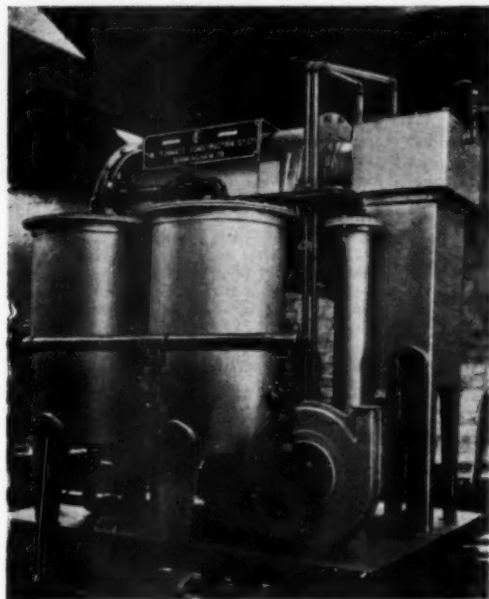
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AP 112

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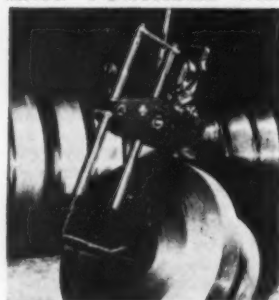
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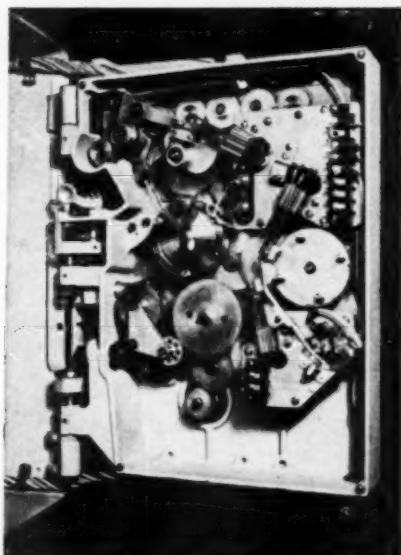
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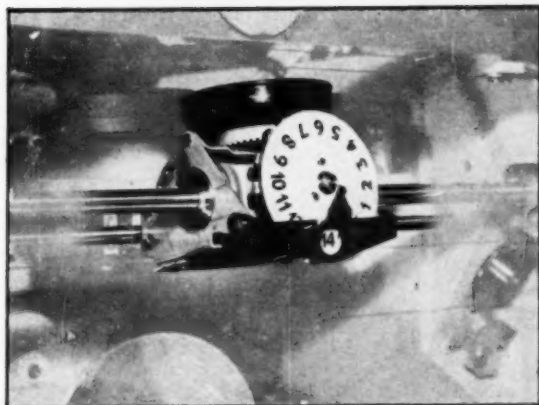
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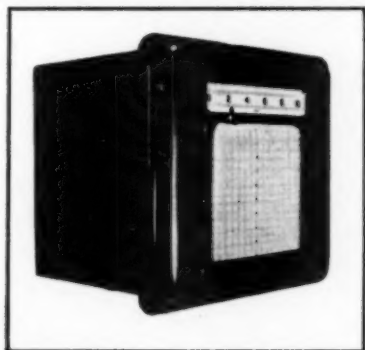
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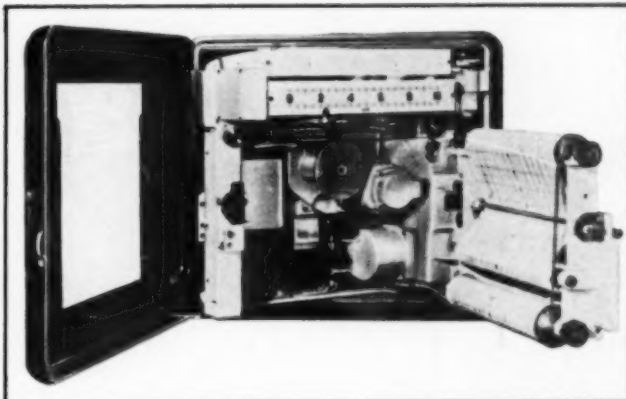


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